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THE PROFILES OF HIGH MASONRY DAMS.

By JOHN B. McMASTER, C. E.

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II.

As this form of profile, therefore, has been illustrated, and its economy, durability and strength fully tested in the case of the dam at Furens, and in that over the Ban, we shall now undertake its investigation, and determine a series of formulæ for the calculation of the logarithmic curves forming the inner and outer face of the dam, and, finally, the establishment of a *profile type* suitable for dams of various heights. Our investigation, moreover, is to be based on the practical experience of MM. Graeff and Mongolfier, in the construction of the dams of Furens and over the Ban, and the brief but thorough report of Professor Rankine on this form of profile, to many parts of which we are greatly indebted.

In the first place, as to the limit of pressure, two questions naturally present themselves: first, what shall be the greatest limit of pressure we may with safety assume? and secondly, is the same limit to be adopted for the inner as for the outer face of the structure? As regards the first question, it becomes evident at a glance that the limit R′, to which any point in the dam may be subjected without thereby endangering stability, will depend, to no small extent, on the nature of the stone, cement, or mortar used. Yet here, as in other cases where masonry is used, it is possible to assign a general limit, based upon practical experience, which should not in any case be overstepped, and if possible rarely equaled. In the two dams to which we have above alluded, the limit of the pressure was taken at 6 kilogrammes per square centimetre, or 60,000 kilogrammes to the square metre, or taking the kilogramme as equal to 2.20485 pounds, 132.291 lbs. per square metre, which in turn is equal to 1.1954 square yards. In Spain, however, and indeed, we believe in some instances in France, the limit of pressure has been taken so high as 14 kilogrammes per centimetre, and the dam found to stand well, but in the majority of cases at from 6 k. to 8.50 k., generally at 6 k., per square centimetre. We may express this pressure in another form much more familiar to English engineers, and take as the limit of pressure for each square foot or square yard, a column of masonry having that area for a base and a height of 160 feet. This is also based on experience, as it is well known that good rubble masonry will, when laid in strong hydraulic cement, bear with safety the pressure arising from the weight of a

column 160 feet in height. Taking, again, the density of masonry as double that of water, this pressure would be equaled by a water column 320 feet high, or a pressure per square foot of 20,000 pounds.

The next question as to whether the limit of pressure should be the same, both for the inner and outer face of the dam, seems to be viewed very differently by different engineers, and to admit in practice of a variety of solutions. In the dams constructed by M. Graeff and M. Mongolfier, and in the theoretical profiles offered by M. de Sazilly and M. Delocre, the same limit of pressure was adopted for each face, and the discussion of the formulæ thus much simplified. Yet there seems to be much ground for departing from this observance and for adopting two limits, one for the outer and one for the inner face, provided that the dam has such a logarithmic curve of profile as that we are considering. It is evident that the vertical pressure along these two faces is, at different times, unequal; that when the water is of great depth behind the dam the outer face is more severely strained than the inner, and that when the water is very low, and the dam has little more than its own weight to resist, directly the opposite result takes place and the severest strain is found along the inner face. It is likewise evident that the pressure at any point along these faces must, in all cases, be of necessity in the direction of the tangent to the surface at that place. If the face is vertical, the quantity we derive by the usual equations is the true vertical pressure, or rather the *entire* pressure. But when the surface slopes off from the vertical, as it does in this case, the pressure is in the direction of the tangent, is *inclined* to the vertical, and the quantity which the formula gives us is not the entire pressure, but only its *vertical* component. The *whole* or *real* pressure of course, exceeds this vertical component, by a ratio which grows greater and greater as we pass down the face of the dam to parts where the batter, or slope of the face, departs more and more largely from the vertical. But the outer face has a very much greater batter than the inner, and the water being high, is subjected to a much greater strain, so that, to equalize matters, and not allow the outer face, when the dam is full, to suffer a greater strain than the inner face when the dam is empty, it becomes most expedient to take a lower limit for the vertical pressure at the outer than we do for the intensity of the vertical pressure at the inner face.

Adopting this view, it remains to fix these two limits of vertical pressure. On the inner face, it is clear, where the slope deviates so very little from the vertical that, for all intents and purposes, it may be safely neglected, we may take that we have already fixed upon, namely, the weight of a column of masonry 160 feet high. For the outer face, we may take a pressure whose vertical component is represented by the weight of a masonry column 120 feet high, a pressure which has been deduced from the practical examples of M. Graeff.

The next matter to be taken into account is that of tension, which must, so far as possible, be avoided in every portion of the dam. And this brings us to the consideration of the "lines of resistance," of which in structures subjected to such varying pressure, there are of necessity two; one for the condition that the dam or reservoir is full of water, and one for the condition that it is empty. As in the case of earth retaining walls and buttresses, these are lines passing through the centre of gravity of each course of masonry, and may, when the faces of the dam are rectilinear, be found by any of the formulæ used for such purposes. They bear, therefore, intimate relations to the stability of the dam, the latter decreasing as they depart from the centre of thickness and near the faces. They also bear relation to the tension, and in order that the latter may not become appreciable in any part of the structure, they must not deviate at any point from the line passing through the centres of thickness, either outward when the dam is full, or inward when empty, by a distance greater than one-sixth of the thickness at that point.

With these conditions in view, we now pass to the consideration of the profile.

PROFILE TYPE FOR DAMS HAVING CURVES FOR BOUNDING FACES.

Let Fig. 9 represent the profile of a dam bound by logarithmic curves, the various equations relative to which we

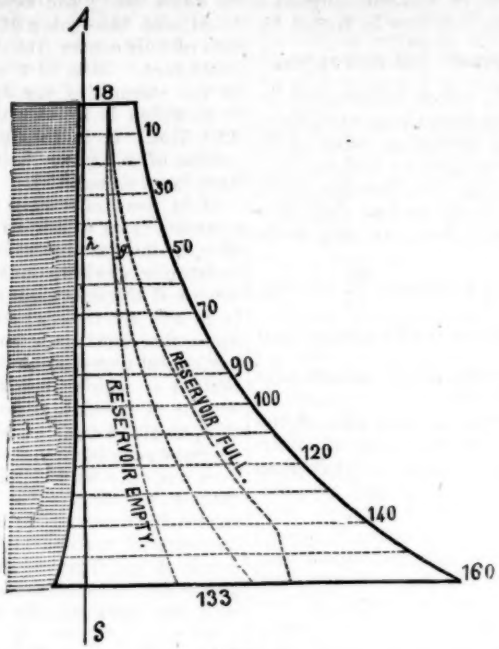

FIG. 9.

wish to find. Let the vertical line A S represent the asymptote of the curves, and taking C as the origin of co-ordinates represent by x all horizontal, and by y all vertical measurements, by b the breadth or thickness of the dam at E D, and by b' the breadth at any other place lower down. Also let s represent the sub-tangent common to the two curves, and represented in the figure by that part of the asymptote contained between F and G. As to the lines of resistance let their deviation from the middle of the thickness when the dam is full and empty be expressed by the letters r and r' respectively, and by R and R′ denote the limits of pressure; the first for the outer, the second for the inner face.

Now, adopting Professor Rankine's method of procedure, it becomes evident that if the thickness across the top be expressed by b, then the thickness at any other portion of the dam lower down, and at a distance y below the top, will be expressed by the equation

$$b' = b.e^{\frac{y}{s}} \quad . \quad . \quad . \quad . \quad . \quad 38.$$

in which e is the modulus of the common system of logarithms, or 0.434294. To apply this equation therefore to practice, it is necessary to know the value of the sub-tangent, the thickness across the top and the vertical distances of different points on the face of the dam below the axis of X. These latter points are, of course, assumed at random, and have in the present case been taken five feet apart. As to the thickness at the top it has been taken at eighteen feet. In the dams already alluded to (those of MM. Sazilly and Mongolfier) with the height of 50 and 42 metres respectively, and a limit of pressure of 60,000 kilogrammes per square metre, the thickness across the top is, in the former, five, and in latter, five and seven-tenths metres, which, expressed in feet, gives for the one 16.4 and for the other 18.6 feet. But in this instance we have slightly enlarged on the thicknesses used by those engineers, in order to produce a profile suited for a dam required to resist not only the thrust of water, but also that of ice when carried down by spring freshets.

The determination of the sub-tangent s is not so obvious, but may be found by giving to the exponent $\frac{y}{s}$ of e an approximate value of $\frac{3}{4}$, which substituted in the formula (to be found below) of Prof. Rankine, gives a corrected value of $\frac{11}{4}$, and a sub-tangent equal to 80 feet.

If, then, adopting this breadth of 18 feet on top, we desire to find that at a point thirty feet below, we may write equation :

$$b'=\log.\ b+0.434294\times\frac{30}{80} \quad . \quad 39.$$

$$=1.255273+0.162858=26.19 \text{ feet;}$$

which is to be measured off in such wise that thirteen-fourteenths of it shall lie on the down stream or outer side of the asymptote, and the remaining one-fourteenth on the up stream or inner side. Taking other values for y and proceeding in precisely the same way, we thus obtain any desired number of points through which must pass the logarithmic curves that form the faces of the dam. This done and the curve drawn, the next step is to determine the lines of resistance when the dam is full and when it is empty. To begin with the latter case, the dam being empty, the deviation of the line of resistance from the middle of the thickness will evidently be *inward* or towards the up stream side of the dam. This deviation we have expressed by the letter r', and if we wish to find its value for a horizontal section of the dam taken 50 feet below the top, we proceed as follows. Let z denote the distance $h\,g$ or the deviation of the centre line of the thickness outward from the axis A S, and by z' the deviation of the same line from the same axis at the top of the dam. Referring to Fig. 9, the distance we wish to find is that denoted by the letters $m\,h$, which is evidently equal to $g\,h-g\,k$, divided by 2, or

$$r'=\frac{z-z'}{2} \quad . \quad . \quad . \quad . \quad 40.$$

Because the dam having only its own weight to carry, the line of resistance must cut the line $g\,h$ in a point vertically below the centre of gravity of that part of the structure above $g\,h$.

The thickness of the dam where y is fifty feet is found from equation 39 to be 33.63 feet; the centre of thickness 16.81, and the value of z or the deviation of this centre from the axis A S is 14.41 feet. That of z' or the deviation at the summit of the dam is 7.72 feet, from which it follows that (eq. 40) $r'=$ 3.35 feet. It is in this way that the values of r', given below in Table A, have been calculated.

It is next necessary to determine an equation from which to find the values of r, or the amount by which the line of resistance deviates outward from the centre of thickness when the dam is full. It is evident this deviation will depend upon three things, the moment of the horizontal thrust of the water, above the section at which we wish to find r, the weight of the dam above this same section, and the amount by which the line of resistance is moved *inward* when the dam has only its own weight to carry, so that if we divide the moment of the thrust by the weight, and *subtract* the quantity r', we shall at once have the value of r. The thrust of the water above any horizontal section of the dam is, as we have already seen by equation 2, $\frac{y^2}{2}\times 62.5$ lbs., and the moment is, therefore, $\frac{y^2}{2}\times 62.5\times\frac{y}{3}=\frac{y^3}{6}$ 62.5 lbs., or, what is the same thing, if we express by w the ratio in which the masonry is heavier than the water, and take, as is usual, this ratio as 2, we shall have for the moment (expressed by m) of the horizontal thrust of the water,

$$m=\frac{y^3}{6\,w}=\frac{y^3}{12} \quad . \quad . \quad . \quad . \quad 41.$$

The weight of any lineal unit of the dam above the section may be found most simply by the calculus. Thus giving to y and b the same signification as before, and taking the weight of a cubic unit of masonry as the unit of weight, the weight of each unit of length of the wall above the section is expressed by

$$W=\int_o^y b'\,dy \quad . \quad . \quad . \quad 42.$$

Integrating this between the limits y and o, and remembering that $b'=b\,e^{\frac{y}{s}}$ we have :

$$W = s\,b\left(e^{\frac{y}{s}}-1\right) = s\left(b.e^{\frac{y}{s}}-b\right)$$
$$= s\,(b'-b) \quad . \quad . \quad . \quad 43.$$

For r, therefore, we have:

$$r+r' = \frac{m}{W}$$

$$r = \frac{m}{W} - r' = \frac{\frac{y^3}{12}}{s\,(b'-b)} - r'$$

or
$$r = \frac{y^3}{12\,s\,(b'-b)} - \frac{z-z'}{2} \quad . \quad 44.$$

This equation gives for the value of r at the distance fifty feet below the top, the quantity 5.18 feet, which, as it falls below one-sixth of the thickness at this point, we are justified in considering the deviation as not too great to be perfectly consistent with stability.

But, to make assurance doubly sure, we may apply a final test as to stability, by calculating the amount of vertical pressure at various points along both the inner and outer faces, and comparing the results with the limit of pressure, which, it will be remembered, has been fixed for the inner face at weight of a column of masonry 160 feet in height, and for the outer face at that of a column 120 feet high. This matter we have already considered at length, and have deduced two equations, 13 and 14, which as they are perfectly suited to the present case, we shall not delay to deduce others, but alter them to suit the notation of Fig. 9. Thus altered they are, calling p and p' the pressures at the outer and inner face respectively, and P and P′ the limit at these same faces—

$$\left.\begin{aligned} p &= 2\left(2-\frac{3u}{b'}\right)\frac{W}{b'} = \text{or} < P \\ \text{and} \quad p &= \frac{2\,W}{3\,u} = \text{or} < P \end{aligned}\right\} \quad 45.$$

While for p' we have two others precisely similar, with the exception that P in equation 45 is changed to P′. It may, perhaps, be well to again remark that the first or second value of p in equation 45 is to be used according as the value of u is greater or less than one-third of the thickness, and that in all such profiles as that of Fig. 9, the quantity u denotes the distance from *the outer face* to the *line of resistance when the dam supports a charge of water*, and from the *inner face* to the *line of resistance when the dam or reservoir is empty*. To illustrate by one example, let it be required to find the vertical pressure at the point C, on the outer face of the dam (Fig. 9), situated fifty feet below the top. By referring to Table A, we see that b' is equal to 33.63 feet, that the outward deviation of the line of resistance is 4.98 feet, and that u must therefore be 11.83 feet. The quantity $W = s\,(b'-b)$ is 1250.4. Since u is here greater than $\frac{b'}{3} = 11.21$, we use the first of equation 45, and, making the substitution of values, we have:

$$p = 2\left(2-\frac{35.49}{33.63}\right)\frac{1250.4}{33.63} = 70.555$$

Thus showing that the pressure is but a little more than half the limiting pressure. Precisely the same operation repeated, with u equal to 13.46 feet, will give the amount of vertical pressure at the inner face at a point fifty feet below the top, the dam supporting only its own weight. This pressure is thus found to be equal to a column of masonry 59.4 feet in height.

The area of the entire profile or of any portion of it, included between two horizontal sections, may be found by taking the difference between the thickness of the dam at these two sections, and multiplying the difference by the subtangent. For it is evident from the figure that, if b equals the thickness of a point y feet from the top, then this thickness multiplied by the differential of the height and integrated between the limits y and zero, is the area, and this expression $\int_0^y b'\,dy$ when integrated, remembering that b' is equal to $b\,e^{\frac{y}{s}}$ gives $s\,b\,e^{\frac{y}{s}} - s\,b$, or replacing $b\,e^{\frac{y}{s}}$ by b', the expression for the area becomes $s\,(b'-b)$. In the notation we have used b means the thickness of the dam across the top, but in calculating the area of any portion of the profile not bounded by the top thickness, the quantity b is to be understood to mean the smaller of the two thicknesses which bound the area. That is to say, if we wish to find the area of that portion of the profile

included between horizontal sections taken at thirty and eighty feet below the top, b represents the thickness at the former section, and we have 80 (48.93 −26.19) = 1819.2 square feet. Having the area, the solid contents and weight for any length of the dam are of course readily found. The areas for sixteen different sections of the profile, each having the top of the dam for one side, have been calculated in this way, and will be found entered in the last column of Table A. The first column of this table gives the distances in feet of the sections estimated from the top downwards, the second the thickness of the dam at these sections, the third the deviation of the line of resistance outward when the reservoir is full, the fourth the deviation inward when empty, and the last the areas.

TABLE A.

		r'	r	Area sq. feet.
0	18.00	0	0	0
10	20.40	.51	.18	192.00
20	23.10	1.09	.54	408.00
30	26.19	1.75	1.68	655.20
40	29.68	2.52	3.18	934.40
50	33.68	3.35	5.18	1254.40
60	38.10	4.53	6.66	1608.00
70	43.17	5.39	8.79	2013.60
80	48.93	6.62	10.52	2474.40
90	54.18	7.75	12.95	2894.40
100	62.97	9.63	13.53	3597.60
110	71.18	11.39	15.02	4254.40
120	81.79	13.62	14.59	5103.20
130	91.39	15.72	15.46	5871.20
140	103.60	18.34	15.05	6848.80
150	115.00	20.78	15.46	7440.00
160	133.00	24.64	12.46	9200.00

It is perhaps unnecessary to call attention to the fact, that this form of profile has been calculated with a view to its serving as a *profile type* for dams of any height, great or small, whose faces are logarithmic curves. For a dam, then, of which the height is thirty feet, that portion of Fig 9, above the line marked 30, is the proper profile: for one eighty feet in height, that portion above the line marked 80, and so for each succeeding section. It presents again many strong points not found in dams of the usual rectilinear profile, which are especially deserving of consideration when damming a river or valley of great breath and depth. Of these not the least is its economy of material, which, as we shall hereafter see, is very great as compared with that of stepped or sloping profiles; while the curves of the two faces are so gradual that no great mechanical difficulty can arise in cutting the facings. Another matter, which, in the dams of Furens and the Ban was not taken into account, that of tension, has here been considered and the profile so determined that when the reservoir is full the tension on the outer face shall not at any point be greater than it is on the inner face when empty.

The profile of the Furens dam is given in Fig. 10, and that constructed on the

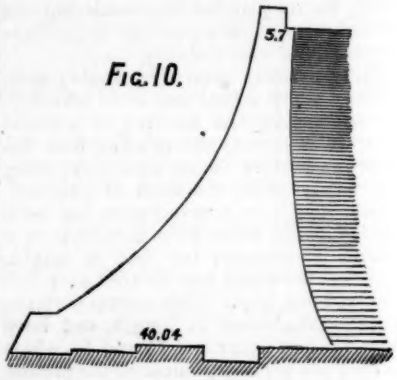

FIG. 10.

Ban, a tributary of the Gier, in Fig. 11.

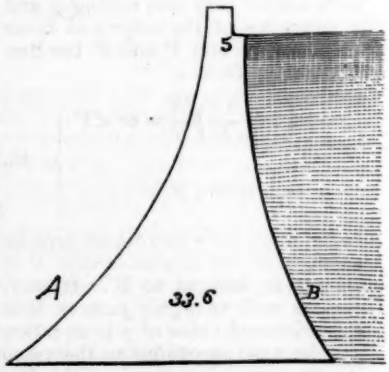

FIG. 11.

The former has a height of fifty metres with a breadth on top of 5.70 metres,

and a limit of pressure of six kilogrammes per square centimetre. The latter has a height of forty-two metres, a thickness on top of five metres, with the same limit of pressure as the Furens dam. By a comparison however, of the profile of the former with that part of the profile of the Furens which lies above the limit A B we see that the thickness has been very considerably reduced, while if we extend the profile to fifty metres and then compare it with the Furens, we find that the pressure nowhere exceeds 8 kilogrammes to the square centimetre.

To return now to the modifications of which this type of profile is susceptible.

MODIFICATIONS OF THE LOGARITHMIC PROFILE.

On a moments inspection of Fig. 8, it is readily seen that, as the inner curve does not anywhere depart very far from the asymptot A S, the first and simplest modification of this curve is to replace it by a right line and thus make the inner face vertical from top to bottom. But the outer curve if treated in like manner, and replaced by a right line, would give us a form of profile which, though it possessed no more thickness at the bottom than was absolutely necessary to withstand the vertical pressure, would at every other point, possess a thickness greatly in excess of the requisite amount, and thus occasion a prodigious waste of masonry. We must therefore, break this continuous slope and substitute for one long line two or more shorter ones each of which makes a different angle with the vertical. Limiting our attention for the present to the first case, and replacing the two logarithmic curves in Fig. 9 by lines,—the inner curve by one vertical, and the outer by two inclined—we have produced for us a profile of the form illustrated in Figs. 12 and 13. The

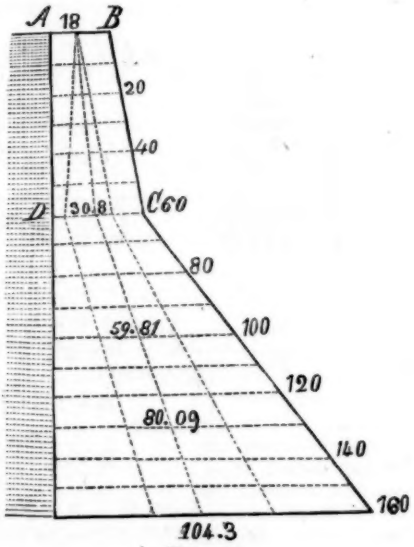

FIG. 12.

question that first presents itself in the discussion of such a profile, is evidently how far down the outer face the point C is to be taken. It comprises indeed, the *entire* discussion. Of course, it is a great advantage, so far as the saving of material is concerned, to throw this point as low as possible, but this is limited by the condition, so necessary to secure stability, that when the reservoir is full the vertical pressure at C shall not be *greater* than the limiting quantity R. Having determined the thickness across the top, which preserving our previous notation, we will call b, the quantities to be determined are first, the vertical dis-

tance of the point C below the top, and second the thickness of the dam at this point, or what is perhaps more easily obtained the *excess* of the thickness at C over the thickness at the top, A B. The distance, A D (Fig. 12) we will call y;

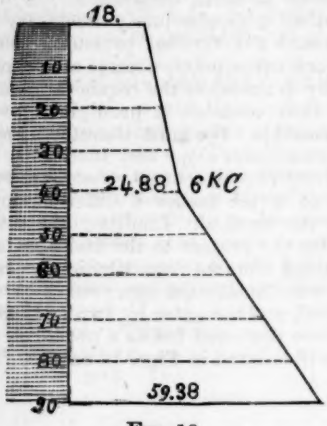

FIG. 13.

the total thickness D C we will represent by b', and express the excess of thickness V C by v. By W, denote the weight of the A B C D (Fig. 14), and by F, the horizontal thrust of the water above D. These two forces act through the centre of gravity O, the former vertically downward and represented in Fig. 14 by

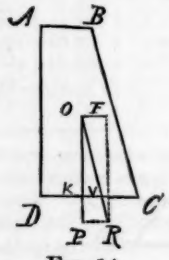

FIG. 14.

the line O P; the latter horizontally and represented in direction and intensity by O F. These two produce a resultant which cuts the base at V, and this point may therefore be regarded as the point of application. From this relation, as we have seen, result two equations $2\left(2-\frac{3u}{l}\right)\frac{P}{l}=$ or $<R'$, and $\frac{2P}{3u}=$ or $<R'$, which are to be used according as u is $>\frac{l}{3}$ or $<\frac{l}{3}$.

In these equations P = W, is, according to the notation of Fig. 14, expressed by $\left(\frac{b+b+v}{2}\right)y\delta'$, in which δ' is the density of the masonry; $l=b'=b+v$ and $u=CV$. But $u=CV=KC-KV$. Now K C may be found by the equation expressing the relation that the moment of the weight of A B C D, with respect to C, is equal to the sum of the moments of the two parts A B V D and B V C into which the area of A B C D may be divided. The moment of the weight of A B C D, with respect to C, is evidently the weight $\left(\frac{2b+v}{2}\right)y\delta'$ multiplied by K C; that of A B V D by $\frac{(b+2v)by\delta'}{2}$ and that of B V C by $\frac{yv^2\delta'}{3}$. Hence, the relation when expressed, becomes:

$$KC\times\left(\frac{2b+v}{2}\right)y\delta'=\frac{(b+2v)by\delta'}{2}+\frac{yv^2\delta'}{3} \quad . \quad . \quad . \quad . \quad 46.$$

$$KC=\frac{\frac{(b+2v)by\delta'}{2}+\frac{yv^2\delta'}{3}}{\left(\frac{2b+v}{2}\right)y\delta'}=\frac{3b^2+6bv+2v^2}{6b+3v} \quad . \quad 47.$$

To find K E, we have from the two similar triangles O K V and O P R the proportion

$$KV:KO::PR:PO$$

whence

$$KV=\frac{KO\times PR}{3P} \text{ or } \quad . \quad . \quad 48.$$

since P R is equal to the horizontal thrust, which, as we see in the early part of our investigations, is equal to $\frac{y^2\delta}{2}$; and since P O is equal to the vertical pressure and this is equal to $\left(\frac{2b+v}{2}\right)y\delta'$ we have finally for the value of K V:

$$KV=\frac{y^2\delta}{3(2b+v)\delta'} \text{ or } KV=\frac{y^2\theta}{3(2b=v)} \quad 49.$$

which latter equation is found by substituting for $\frac{\delta}{\delta'}$ the letter θ. These values given in equations 49 and 47 when replaced in the expression

$$u = K C - K V$$

give $$u = \frac{3b + 6bv + 2v^2}{6b + 3v} - \frac{y^2\theta}{3(2b+v)}$$

$$= \frac{2v(v+3b) + 3v^2 - \theta y^2}{6b + 3v} \quad . \quad 50.$$

With this value of u we return to equations 24 and 25, and, substituting it, we obtain :

$$2\left\{2 - \frac{6v^2 + 18bv + 9v^2 - 3\theta y^2}{6b + 3v}\right\} \times \frac{\left(\frac{2b+v}{2}\right) y\delta'}{\delta'\lambda} = \lambda$$

and $$\frac{2\left(\frac{2b+v}{2}\right) y\delta'}{3\delta'\left(\frac{2v^2 + 3b + 3v^2 - \theta y^2}{6b + 3v}\right)} = \lambda$$

These, when reduced and made equal to zero, give us two equations containing two unknown qualities :

$$y^3 - \lambda v^2 - 2b\lambda v + b^2 y - \lambda b^2 = 0 \quad . \quad 51.$$

$$v^2 y - 2\lambda v^2 - 4bvy + \theta\lambda y^3 - 6b\lambda v + 4b^2 y - 3b^2\lambda = 0 \quad . \quad . \quad 52.$$

The first of which is to be used when $u > \frac{b}{3}$, and the second when $u < \frac{b}{3}$. Each of these equations express the relation that when the reservoir is full the vertical pressure at the point C (Fig. 14) shall be equal to the limit R. But we must also take into consideration the inner face, and find an equation expressing the relation that the reservoir being empty, the pressure at D, shall not exceed the limit R. In this case, the face being vertical, the pressure of the water does not exist, and the force P, or the weight of this portion of the dam, acts downwards through the centre of gravity, and

$$u = D K = D C - C K$$

$$u = b + v - \frac{2v(v+3b) + 3b^2}{6b' + 3v}$$

$$= \frac{6b^2 + 6bv + 3bv + 3v^2 - 2v^2 - 6bv + 3b^2}{6b + 3v}$$

$$= \frac{v(v+3b) + 3b^2}{3(2b+v)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad 53.$$

With this value of u, we again return to equations 24 and 25, substitute in each, and reducing, have :

54.
$$v^3 y - v^2\lambda + 3by v - 2b\lambda v + b^2 y - \lambda b^2 = 0$$

55.
$$v^2 y - v^2\lambda + 4byv - 3b\lambda v + 4b^2 y - 3b^2\lambda = 0$$

By combining 51 and 54, or 52 and 55, we may readily obtain the value of y and v, which are the two quantities we wish to find. It is moreover to be remarked that λ in the above equations is found by dividing the limit of vertical pressure at C and D by the ratio in which the masonry is heavier than water. Thus in calculating the profile of Fig. 12, we have first reduced the limit of vertical pressure per unit of surface from pounds to kilogrammes, and taking the density of water, as given in the French tables, as 1000 kilogrammes and the density of masonry as double that of water or 2000 kilogrammes, we have $\lambda = \frac{R}{2{,}000} = \frac{60{,}000\,k}{2{,}000\,k}$ or $\lambda = 30$. We thus obtain for λ, a very simple number, whereas had we retained the pressure as expressed in pounds, we would have had a much larger one to handle. In Fig. 13 however, in order to produce a profile of what may be considered as a type of the greatest boldness consistent with safety, we have taken the limit of vertical pressure at 14 kilogrammes per square centimetre, which as we have already stated has been used in several instances in France and Spain. This increases the value of λ to 70. The thickness across the top is in each case the same as in that of the profile illustrated in Fig. 9 ; namely, eighteen feet, but the height of that in Fig. 12 has been reduced to ninety feet. The height A D of the upper part A B C D and the value of v corresponding to it have been found by combining equations 51 and 54. The lower part, by the same equation, by substituting for y the difference between the height A D of the upper part and the entire height of the dam.

The deviation of the line of resistance when the reservoir is full may also be found as follows. Let A B C D in Fig. 15, represent either the upper or lower

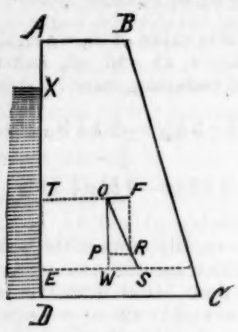

FIG. 15.

part of the dam whose profile is given in Fig. 13, and let it be desired to find the amount of deviation at any section as E F. By O represent the centre of gravity of A B F E, then will O R represent the resultant of the two forces acting on this portion of the dam, and the distance we wish to find will be E S. We will suppose also, in order to cover all cases that the water stands at X. Also let $AB = b$; $AX = l$. $AE = y$; $ES = x$; $EW = h$; and the inclination of the sloping side B C, to the vertical be denoted by α; by δ the density of the masonry and by δ' that of the water. Then by the similar triangles O P R and O W S, we have:

$$\frac{WS}{OW} = \frac{PR}{OP}$$

Now $WS = ES - EW = x - h$ and $OW = TE = \frac{1}{3}XE$ because the centre of pressure (T) of a rectangular plane surface sustaining the pressure of water, is at a point two-thirds the depth of its immersion. Hence $TE = \frac{1}{3}(y - l)$. P R or the horizontal thrust of the water on X E is, as we know, expressed by $\frac{\delta'(y-l)^2}{2}$; and the pressure O P by $\frac{(b+b')y\delta}{2}$ or $\frac{(2b+y\tan.\alpha)y\delta}{2}$

$$\therefore \frac{x-h}{\frac{1}{3}(y-l)} = \frac{\frac{1}{2}\delta'(y-l)^2}{\frac{1}{2}y\delta(2by+2y^2\tan.\alpha)\delta} \qquad 56.$$

Then replacing $\frac{\delta'}{\delta}$ by θ

$$x - h = \left(\frac{(y-l)^2}{2by+y^2\tan.\alpha}\right)\frac{1}{3\theta} \quad . \quad 57.$$

But $h = \frac{\frac{1}{3}y^2\tan.^2\alpha + by^2\tan.\alpha + b^2y}{2by+y^2\tan.\alpha}$

which, added to equation 56, gives:

$$x = \frac{\frac{1}{3\theta}(y-l)^2 + \frac{1}{3}y^2\tan.^2\alpha + by^2\tan.\alpha + b^2y}{2by+y^2\tan.\alpha} \qquad 58.$$

This value of x is, of course, to be measured off *from* the vertical side. When the water stands at the top of the dam, the value of l, is zero, but when the reservoir is empty, then l, is equal to the entire height of the dam. The simplest way, however, to find the deviation, is by means of Equation 50, observing that the value of u, when found is to be laid off from the outer or sloping face of the dam; and corresponds to the distance F S in Fig. 15.

THE MARINE COMPASS—CONSIDERATIONS RELATIVE TO CERTAIN FUNDAMENTAL REQUIREMENTS OF IT, WITH SPECIAL REFERENCE TO THE CONSTRUCTION OF THE NAVY COMPASS.

BY PROFESSOR B. F. GREENE, U. S. N., Superintendent of Compasses, Bureau of Navigation.

Proceedings of United States Naval Institute.

I.

INTRODUCTORY OBSERVATIONS.

It is sufficiently well known to the members of the Naval Institute that a change in the compass equipment of our ships of war has been gradually going on for a number of years past, until there has come to be nearly a complete substitution of the liquid compass for

the air or dry compass previously in use.

The first introduction into our service of this kind of compass was about eleven or twelve years ago, in the form of a liquid boat-compass, the original models of which were imported compasses of English make, with flat porcelain cards.

The superiority of these instruments over the old and comparatively useless form of air boat-compass was soon evident and generally acknowledged; and yet, for various reasons (possibly from a little conservative prejudice), the new compass was only partially accepted, the outfit for boat equipment continuing for some time to consist partly of liquid and partly of air compasses.

Meanwhile, Mr. E. S. Ritchie, of Boston, who had long been distinguished for his intelligence and skill as a maker of the higher grades of philosophical instruments, finding it expedient, like many others at that time, to turn his attention to the fabrication of "war material" of some kind, solicited and obtained orders to make compasses for the Navy. It was thus that, while making some liquid boat-compasses after the English model, he was led to propose an important improvement, in the substitution of a *buoyant card, with a pivot-pressure entirely at control*, instead of the heavy flat disk otherwise in use.

This was the fruitful germ of Mr. Ritchie's idea, which, from the time he first put it into a practical form, has been in course of continued development, until the compass of the past year, although preserving its original distinctive features, is immeasurably the superior of its early predecessor in all the details of its construction.

Still, our naval authorities, while admitting the improvement, were far from precipitate in changing the compass equipment of our ships; and thus it happened that the new liquid compass was hardly brought into exclusive use, even for the steering-binnacle, until about five years ago, and for azimuth purposes only during the last two or three years. In reality, however, it is but few years since the first attempt was made to adapt the compass-card to azimuth observations by giving it a suitably-divided circle; and it is only within the past year that I have been satisfied the true construction of the compass-card had been finally reached.

It was thus by these cautious and tentative steps, and rather behind than in advance of established convictions, that the liquid compass came at length into general use in the Navy; and the time has arrived when we may, I think, with some propriety, put on record, in a public manner, some of the reasons which have appeared to justify a position in this regard so much at variance with the general practice of all other countries.

I propose, therefore, with your indulgence on this occasion, to present a few considerations relative to the principles which, as I am led to believe, should control the construction of the marine compass; and then, by way of application, to show wherein our practical conclusions have been, or are likely to be, justified by the particular type of compass now recognized in our naval service.

The subject is certainly not a hackneyed one; for, notwithstanding the considerable antiquity of the marine compass, in the general form by which it has been known to the nations of Western civilization—with volumes of history, popular description, and panegyric—I am not aware that a single attempt has hitherto been made to give a rational explanation of its magneto-mechanical action, or of the principles upon which its construction, as an instrument of observation, should depend. And yet the theory of this instrument rests upon a few simple considerations of certain established conclusions of science. The neglect in this particular may, perhaps, afford a sufficient explanation of what appeared, in my first acquaintance with the marine compass, as one of the most remarkable facts in its history—that, as commonly seen in the hands of navigators, *it should be one of the rudest and most imperfect instruments for the accomplishment of one of the most important purposes among the practical pursuits of life.*

There are three properties of the marine compass, so essential to its reliable action and convenient use that they may very properly be regarded as fundamental desiderata. They are:

MAGNET-POWER, SENSIBILITY, STEADINESS.

Let us consider, for a few moments, the precise significance of these terms in their present application; the conditions that appear to be requisite for the most favorable realization of the properties which they represent; and how nearly they are likely to be satisfied by the present Navy compass.

I. MAGNET-POWER OF THE COMPASS.

The more or less complex system called a compass-card, alike with the simple magnetic needle, when balanced for motion in a horizontal plane, has a tendency to return to its position of equilibrium, or rest, whenever deflected from it, which may be called its *moment of deflection*.

The moment of deflection is equal to the *moment of motive force* less the *moment of resisting force*. The moment of motive force is composed of three factors: of which one is the magnet-power (or, perhaps, in more precise phrase, the magnetic moment) of the card; another is the directive force acting on the compass, meaning the whole exterior magnetic force acting in the horizontal plane of the card; and the third factor is the sine of the angle by which the zero-line of the card is deflected from its position of rest.

The moment of resistance is the moment of all the resistances, of whatever kind, to the motion of the card.

All these moments are referred to the point of the pivot as the centre of the compass and centre of moments.*

In relation to the *directive force*, it will here be understood that this term refers to the whole external magnetic force actually effective upon the compass; this being known, in general, on shore, as the horizontal magnetic force of the earth, and on board ship as the resultant of the horizontal magnetic forces of the earth and ship, for the particular heading of the ship, the particular place, and the particular time under consideration.

And, similarly, in relation to the *position of rest*, it will also be understood that the zero-line of the card (supposed to coincide with the magnetic axis of the card), while at rest, is in the position of equilibrium in respect of all the forces, magnetic and otherwise, acting upon it; this being known, in general, on shore, as the magnetic meridian or direction of the earth's horizontal magnetic force, and on board ship as the deviated direction of the compass, or resultant direction of the directive force on board.

The moment of motive force, the directive force remaining the same, varies, therefore, with the magnet-power of the card multiplied into the sine of deflection. It is *greatest* as the card is deflected 90 degrees from its position of rest, when the moment of deflection is equal to product of the magnet-power by the directive force, less the moment of resistance; and it is *least* as the card comes to rest, at or near its previous position, when the moment of deflection is equal to zero; the moment of the motive force being reduced to an equality with the moment of resistance, whatever that may be.

Accordingly, we have for the sine of the *angle of set* (or terminal angle of deflection), or for the arc of set, if the angle be not very large *the moment of resistance divided by the product of the magnet-power and directive force.**

In order, therefore, that the card may always return exactly, or very nearly, to its position of rest, whenever deflected from it, it is necessary either that the moment of resistance be extremely small in comparison with the product of the magnet-power by the directive force,

* If M represent the magnet-power of the card, H the directive force acting upon the card, and δ the angle of deflection of the zero-line of the card, then the moment of motive force, or moment of rotation, tending to restore the card to its position of rest, or statical equilibrium, is expressed by the product of M and H into the sine of the deflection from the direction of H; or,

$$\text{Moment of motive force} = MH \sin. \delta$$

Putting, also, R for the moment of all the resistances, and the moment of deflection is equal to the difference of these two moments; or,

$$\text{Moment of deflection} = MH \sin. \delta - R$$

* When the deflection $\delta = 90°$, we have the maximum—

$$\text{Moment of deflection} = MH - R$$

and when the card comes to rest, the minimum—

$$\text{Moment of deflection} = 0 = MH \sin. \delta - R$$

and, accordingly, the sine of the angle of set,

$$\sin. \delta = \frac{R}{MH}$$

or the arc of set, if small,

$$\delta = \frac{R}{MH}$$

or that this product be extremely large in comparison with the moment of resistance.

Now, the directive force of the earth, in different places traversed by the navigator, varies from about one-half to about twice its mean value; while the directive force on board, especially of iron-built ships, may vary quite as much on different courses of the ship, even in the same locality. Consequently, if, from developed defects of the compass, the moment of resistance be unavoidably large, or, on the other hand, if the directive force on board be much below its mean value, the angle of set, even with the magnet-power of the card unimpaired, will become so much the more appreciable.

It is, therefore, quite essential to the reliable behavior of the compass, under the varying circumstances of a ship's cruise in different parts of the world—

First, that the magnet-power of the compass-card should be as great, in every case, as can be conferred upon it, compatibly with other necessary conditions; or, in other words, that our aim should be to procure not only enough magnet-power for ordinary or average circumstances, but a surplus or reserve for extraordinary occasions of special requirement.

Secondly, that the magnet-power of the card should be as nearly permanent as can be realized through the formation of the card-magnets; and, to this end, that the greatest care should be used during every stage of that process.

Estimating the magnet-power of a compass-card.—These conditions will, perhaps, be more truly appreciated if we consider for a moment the means by which the magnet-power of a compass may be correctly estimated. Three different methods may be employed, with greater or less convenience, for this purpose.

First, the method of deflections.—By this (statical) method, the compass-card whose magnet-power is required is made to deflect a standard magnetic needle at a certain measured distance between their respective centres. The magnet-power of the card is then equal to one-half the cube of the distance multiplied by the product of two factors, of which one is the tangent of the observed deflection, and the other is the directive force; it being understood that the card is so presented toward the magnetic needle that its zero-line is in the magnetic equatorial through the centre of needle.

Secondly, the method of oscillations.—By this (dynamical) method, the compass-card is made to oscillate in its own plane, and the time of one oscillation noted. The magnet-power is then equal to three-tenths of the moment of inertia of the compass-card, divided by the product of two factors, of which one is the square of the oscillation-time and the other is the directive force; it being understood that the units of distance and time are the foot and second.

For the same card, the moment of inertia is constant, and the magnet-power is proportional inversely to the square of the oscillation-time multiplied by the directive force.

For different cards, with the use of the same auxiliary weight, the moment of inertia of the card may be expressed in terms of the moment of inertia of the weight; and the magnet-power is then proportional inversely to the difference in the squares of the oscillation times (with and without the weight) multiplied by the directive force.

Thirdly, the method of torsions.—By this (also a statical) method, the compass-card is suspended in a torsion-balance, and the moment of deflection at any angle balanced by the corresponding moment of torsion. In this case, the magnet-power of the card is equal to the moment of torsion divided by the product of two factors, of which one is the sine of the deflection and the other the directive force.

For the same conditions of torsion, the moment of torsion varies directly as the angles of torsion; and, accordingly, with the same angle of deflection, the magnet-power of any compass-card is proportional directly to the angle of torsion divided by the directive force.

The directive force is thus seen to be an element in each of these methods, as, indeed, it must necessarily be in every estimate of the magnet-power of a compass-card, or of any simple magnetic needle. Still, so long as the required determinations are made at the same place on land, it will be sufficiently exact, within moderate periods, to regard the directive force as constant, in which

case the proportionality of the magnet-power is independent of the directive force.

But, as already mentioned, since this element, under the combined influence of geographical position and the ship's heading, may vary in a several-fold ratio, a proportional change must result in the remaining elements of the determination, provided the magnet-power of the card is unchanged. Hence, generally, in order to any reliable estimate of the magnet-power of a compass, under the varying circumstances of its use at sea, *the directive force must always be known as a necessary preliminary.*

Now, there is no physical difficulty in obtaining absolute determinations of the directive force by well-known methods whenever required; and with this element absolute determinations of the magnet-power of a compass-card could be had, if desired, by either of the foregoing methods. Nevertheless, for all practical purposes connected with the use of the compass, it is always quite sufficient to obtain relative values of the magnet-power for the directive force taken as unity at some convenient initial point.

It would lead me too far from the immediate object of this communication to enter more into details, of a purely determinative kind, in relation to the magnet-power of a compass. It may be sufficient to say, in passing, that the relative directive force, either on board or on shore, may always be found by very simple means, and with sufficient precision for the purpose in view. With respect to the several methods indicated, the second has certain advantages for use at sea: first, that no auxiliary instrument is required; and, secondly, that the removal of the card from the compass-bowl is unnecessary, which, in the case of the liquid compass, is attended with some inconvenience.

Developing the magnet-power of a compass-card.—Now, with respect to the two conditions of the magnet-power previously noted, it will be evident, from the second of the preceding methods, that the question of gaining magnet-power in a compass-card will depend on the possibility of producing a greater increase in the moment of inertia of the card than in the square of its oscillation-time. If, by introducing a different weight and distribution of steel, the moment of inertia is thereby increased m times, while the square of the time is only increased n times, n being *less* than m, there is a *gain* of magnet-power in the ratio of m to n.

Practically, this question resolves itself into two parts: first, that of increasing the magnet-power in the formation of single magnets of given weights and dimensions; and, secondly, that of distributing the magnets upon the compass-card in a manner to increase the magnet power of the card.

First, the development of magnet-power in the formation of single magnets.—This question, which is essentially one of experimental research, has been the subject of numerous special investigations; but by far the most exhaustive inquiry which has ever been made, although open, perhaps, to criticism on certain unimportant points, was that of the late Rev. Dr. Scoresby,* from whose elaborate research the following conclusions may be summarized, as applicable to our present subject:

1. That the selection of steel for compass-magnets should be made from that known generally as the "very best," in the form of thin plates.

2. That the steel, after being cut into pieces of the requisite length and width, should be hardened uniformly throughout, and only annealed or tempered sufficiently to prevent too great brittleness.

3. That the hardened laminæ should be magnetized to their utmost capacity by the most powerful inductive action at command, and each lamina separately tested for magnet-power.

4. That the magnetized laminæ, after being laid together, *in contact*, with the like poles pointing in the same direction, should again be separately tested for magnet-power, and all rejected that show any sensible deterioration.

5. That the proved laminæ should finally be built up in magnet-piles of two or more laminæ in each; it having been conclusively shown that a *compound* magnet, consisting of several proved magnetized laminæ, takes on a higher development of magnet-power than a

* "Magnetic Investigations." By the Rev. William Scoresby, D. D. London, 1843.

simple magnet, in one piece of the same weight and dimensions.

It is not, however, to be understood that the gain in magnet-power from piling is proportional to the number of laminæ in the pile; on the contrary, with equal increments of steel, the corresponding increments of magnet-power are successively smaller, decreasing, approximately at least, in a geometrical ratio with the number of laminæ added to the pile; so that the practical limit of available gain in this manner is soon reached.

The conclusions of Scoresby, established more than thirty years ago, with respect to the formation of compass-magnets, have been frequently confirmed, although little has been added thereto since that time.

These several conclusions may, therefore be adopted, until, at least, we are better informed, not only as the rules of procedure in obtaining compass-magnets of the highest *intensity*, but as also generally favorable to securing them of the greatest *permanency*.

At the present time, with the use of the comparatively unlimited resources of electro-magnetic induction, the means of magnetization are greatly in advance of those employed by Scoresby. Quite recently a means of heating and tempering the laminæ for compass-magnets has been used by Mr. E. S. Ritchie, which ensures much greater uniformity, not only in the distribution of the degree of hardness sought, but also in the subsequent magnetization.

Secondly, the development of magnet-power in the distribution of magnets upon a compass-card.—If a magnet of uniform section be placed across the centre of a card-circle, its length being equal to the diameter of that circle, its magnet-power and weight will be proportional to the diameter, and its moment of inertia to the cube of the diameter. If, now, we conceive this magnet to be moved in either direction outward, parallel to its first position, taking up positions and reductions of length according to the successive chords, its weight and magnet-power will progressively decrease in proportion to the cosine of the angular distance of the chord from the diameter, while its moment of inertia will progressively *increase* in proportion to a certain function of that angle, reaching it maximum at an angle of 45°, after which it will diminish, till, at the angle of 90°, the chord and all that depend on it vanish together.

Thus, with a magnet at the angular distance of 45° from the centre, its weight and magnet-power are each decreased to 0.7 and its moment of inertia increased to 1.4 of their values, in comparison with a magnet equal to the diameter of the centre; and if two such magnets be placed upon two equal parallel chords at 45°, each of these qualities will be doubled, or their weight and magnet-power each be 1.4 and their moment of inertia 2.8. Hence, it may be concluded that, by placing magnets symmetrically on equal parallel chords, it is possible to gain in magnet-power, though at the expense of additional weight to be carried by the compass-card.

It will be shown hereafter that there are certain considerations which establish a choice of these symmetric chords for magnet positions. There are two such arrangements which are substantially equivalent, namely, the single pair on chords at 30°, and the double pair on chords at 15° and 45° respectively. The following table illustrates these several relations at one view:

Distribution of Magnets on a Card.

Designation.	One Magnet at Centre.	One pair of Magnets on Chords at 30°.	Two Pairs of Magnets.		
			On Chords at 15°.	On Chords at 45°.	Sum.
Magnet-Power..... ...	1.0	1.7	1.9	1.4	3.3
Moment of Inertia.....	1.0	2.6	2.2	2.8	5.0
Weight of Magnets.... ...	1.0	1.7	1.8	1.4	3.3

Thus it may be seen that, in assuming a certain practical limit to the increase of section by piling magnetic laminæ in the formation of single magnets (which would be essentially the same for lengths varying between 1.0 and 0.5), and distributing these magnets of equal section upon the parallel chords, according to either of the above-named systems, there will be a material gain in magnet-power, and a larger gain in the moment of inertia, in comparison with the single magnet at the centre.

II.—SENSIBILITY OF THE COMPASS.

If a compass-card on being deflected to any extent in either direction from its position of rest, and then left to itself, return precisely to that position, it may be said to possess *perfect sensibility*; but, on the contrary, if it fail to come precisely to its previous position, the angle of set by which it deviates from that position may be called its *defect of sensibility*.

Now, if there were no resistances to the motion of a compass-card, and if it had any appreciable magnet-power, it would invariably return to its previous position of equilibrium, whenever deflected from it by virtue of the motive action of its deflection, and, consequently, no defect of sensibility could arise.

But, in point of fact, it is a physical impossibility that there should be no resistance to the motion of any body within our immediate cognizance; and, consequently, we must expect, in accordance with our previous assumption, an angle of set, or defect of sensibility, whose value is represented by *the moment of resistance divided by the product of the magnet-power of the card and the directive force acting upon it.*

There are, in reality, two different resistances to the motion of the card: one is the friction of the pivot; the other is the resistance of the medium, air or liquid, in which the card moves within the compass-bowl. The former is a constant; the latter is a variable, depending on the velocity of the card at any particular instant of its motion. The moment of resistance, already referred to, consists, therefore, of the moment of friction at the pivot and the moment of resistance in the medium, both moments being referred to the point of the pivot as the centre of moments. The moment of resistance opposes the motion alike during the increase and during the decrease of the angle of deflection.

The moment of friction consists of three factors: the pressure between the rubbing surfaces, the mean radius of the area in contact, and the coefficient of friction; the latter depending on the physical qualities of the pivot and cap, such as hardness, smoothness, etc. All these factors are essentially constant for the same card, except as they may be liable to change with changes of condition.

The resistance of the medium is more complex; for it not only involves several distinct elements, but its law of action is somewhat uncertain under considerably varied circumstances of the form and velocity of the moving body. Nevertheless, it appears to be certain that the resistance of a medium, properly so-called, is solely a function of the velocity, of the moving body, involving no absolute term independent of that velocity. As to the form of this function, it is far less certain; but we are justified, from the results of experimental research on this subject, in concluding that the moment of resistance of the medium to the motion of a body of unyielding form, like that of a compass-card, is represented by a product of five factors—the square of the velocity of the card, its section of resistance, the mean radius of that section, the density of the medium, and the coefficient of resistance; the latter depending on the form of the card, and possibly, also, on the velocity, in view of the considerable variation in this element during the motions of the card. Of these factors, all but the first and fifth are sensibly constant for the same compass; and of the fifth there is only some doubt whether it can always be expressed as a constant for the same compass, or must be modified somewhat for the variable velocity.

THE report of the Swansea Wagon Company, presented at the ordinary meeting, shows a disposable balance of £14,110 18s. 11d., of which £5,919 18s. will be paid in dividend on the preference and original shares.

OCEAN STEAMSHIP NAVIGATION—ITS PERILS, AND HOW TO AVERT THEM.

By Capt. S. P. GRIFFIN.

Written for Van Nostrand's Magazine.

II.

With the knowledge thus obtained, we can proceed to select a suitable instrument for making sound signals. It is not worth while to speak of the bell, except to condemn it as being unfit for sea coast use. It may do tolerably well about harbors, in narrow channels, on light boats for local purposes only, but as an aid to navigation, to a vessel running in from sea, it is almost worse than useless, because it may deceive the man who has not had any experience with it, he trusting to hear its tones at the regulation distance, runs on until he becomes involved in perils that are speedily followed by destruction.

The steam whistle is a great improvement upon the bell, and the steam siren is superior to the whistle. Of the latter instrument, Professor Tyndall remarks: "That in almost all cases it may certainly be relied on at a distance of two miles."

Professor Tyndall is high authority, and as the scientific adviser of the Elder Brethren of the Trinity House, he conducted an inquiry into the subject of fog signals, commencing in May, 1873. The instruments with which he experimented were air trumpets, horns with vibrating steel rods, air whistles, steam whistles, an American siren, and three guns, one an eighteen pounder, a five and a half inch howitzer, and a thirteen inch mortar; gongs and bells were not included, because previous observations had clearly proved their inferiority to trumpets and whistles.

Seamen have always known that sounds are transmitted best from an elevated station; in a heavy gale you can distinctly hear the voices of the men aloft, whilst at times they cannot hear a word from deck, even when a trumpet is used. Seamen have known also from circumstances of very common occurrence in their experience, that a fog is very favorable for conveying sound. These two important facts they learn in the school of practice. The Professor learned them after a series of elaborately conducted experiments.

Professor Tyndall established two stations for his experiments, one at the top, the other at the bottom of the South Foreland Cliff; a vertical distance of 195 feet separated them; "Comparative experiments at the outset gave a slight advantage to the upper instruments, they, therefore, for the most part were employed throughout the subsequent inquiry." In a paragraph towards the close of his report, the Professor says: "Happily, the experiments thus far made are perfectly concurrent in indicating that at the particular time when fog signals are needed, the air, holding the fog in suspension is in a highly homogeneous condition, hence, it is in the highest degree probable that in the case of fog, we may rely upon the signals being effective at far greater distances." This I suppose is enough to settle the questions as to the advantages to be derived from an elevated signal station for sounds and the superior condition of the atmosphere during fogs for their transmission.

Professor Tyndall gives a preference to the American siren over all of the other competing instruments; however, he speaks of the gun as being "entitled to rank as a first class signal," and recommends that further experiments be made with it, and that it ought to be of the most suitable description, also that the commanders of the Holyhead boats are unanimous in their commendation of it.

The guns used by the Professor in the course of his experiments, it is seen, were not of the right description, they did not burn enough powder, and they were entirely unaided by any acoustic device. We have seen the old-fashioned, long thirty-two pounder tried with eight pounds of powder, and have heard it at remote distances—the guns of a frigate, firing a salute in Monterey Bay, were heard in San Francisco Bay, the distance

in an air line being 75 miles. At Sandy-hook, a striking contrast in favor of guns over the fog signal instrument mounted there, has been repeatedly observed; beyond the farthest reach of the steam siren, vessels heard distinctly the reports of the guns that were undergoing tests at that place.

Seamen have great faith in the superiority of guns for producing fog signals; they believe that the report of a gun of suitable dimensions can be heard at a greater distance than the blast of a steam whistle, or the more powerful sound of a siren; they know that at night its flash can be seen through a fog of no mean density; they feel a confidence in guns, that they have not in favor of any other instrument, and as aids to navigation are intended for the benefit of the navigators, let them have what they know to be the best to suit their necessities, and in the name of common sense, under any circumstances, let them be consulted, let them have a voice in the selection of instruments, and locations for mounting them.

There are plenty of old guns retained by Government about the navy yards, condemned as useless for purposes of war, let us have them to subserve the interests of peace. Mount one of these guns upon an elevated platform ashore, or on the deck of a light-boat, and during periods of fog fire it at intervals of five minutes, using eight pounds of powder, wherever a sea coast fog signal is needed, and most assuredly there will be fewer vessels lost than there are now. Late papers tell us that the Admiralty, alarmed at the loss of the Vanguard by collision with a consort in a fog, has ordered that in future guns shall be used as fog signal instruments.

To convey the human voice to more than ordinary distances man uses a trumpet; to transmit the sound of a siren a trumpet is also used; then give the gun a chance, and send its loud mouthed report with thundering echoes through a trumpet too. Steam whistles and sirens of the present power may be good enough for coasters, pilot boats, and for other vessels that have had a fresh departure, but they are only a little better than the bell to the ship running in from sea guided by dead reckoning alone, for the limit of their sound leaves too small a margin beyond the danger line. The change to the gun will be easy enough; the only expense will be in transporting it to its assigned place and mounting it; it will hardly require additional hands to the present complement allowed to fog stations, the powder can be drawn from what is annually condemned as not being up to the standard in strength for projectiles, but still retaining enough of its noisy properties.

At the time when this paper was first written, the intelligence of the loss of the German steamship Schiller, Captain Thomas, was just received. Her case was used to illustrate the importance of what has been said about needed reforms, and as it is, doubtless, very well remembered, I will use it now. Since her terrible wreck on the Scilly Islands, nothing has occurred to change my views as to the causes that brought it to pass, and it is a peculiarly interesting one, for it occurred upon a familiar route, and it embraces completely the reasoning that has been adopted in the preceding pages.

The Schiller was a large full-powered first class steamship, about a year old, thoroughly equipped and well manned. She was one of a line of steamers in the trade between New York and Hamburg, calling at a port or ports in the English Channel. In pursuing the course usually followed by vessels of her line, she would have passed south of the Scilly Islands, but well within the limit of visibility of Bishop's Rock light, and then she would have hauled in for Plymouth, her destination.

Bishop's Rock, the southwesternmost outlying danger of the Scilly Islands, has a light and a bell upon it; in nights of clear weather, the light shines forth its warning rays to a distance of sixteen miles; in fogs, it is, of course, obscured and useless as an aid to navigation, and the bell is called into requisition to perform a service that it is not equal to.

By the reports that have come to us, we learn that this important steamship had been without astronomical observations for position for three days immediately preceding the wreck; that the weather had been thick and stormy, that her captain had been on deck several days and nights consecutively; that at 9 P. M. of the 7th May, in a dense fog with a breeze from S. W., believing the

ship to be close to the land, the order was given to take in all sail, the courses was altered to S. E., and the engines slowed down to give a speed of ten knots through the water. At 10 P. M., one hour after altering the course, one hour at a speed of ten knots, she struck on Retarriere Ledge, a danger situated S. E. ⅛ths of one mile from Bishop's Rock. Unhappily, she ran ashore at the period of low water, for the rising tide had much to do with the loss of life that followed.

Three days before the wreck, the Schiller was about one thousand miles west of the Scilly's in bad weather. It is anxious work to run in from the wild Western Ocean, and to straighten up Channel by dead reckoning alone; and it was good navigation on the part of Captain Thomas to run his steamship through cloud and mist and fog along a track so closely approximating to the true one, and it was his great misfortune to be at last thrown off by insufficient allowance for currents or for local attraction as he came up with the rocks. He believed that he was near Bishop's Rock at 9 P. M., and he did what he thought to be at the time necessary for the safety of his ship, he took in sail, reduced the speed, and headed more to the southward.

The sixty fathom curve of soundings sweeps around in the arc of a circle of which Bishop's Rock is the centre, having a radius of fifteen miles, the fifty fathom curve with a radius of five miles, and the forty fathom curve approaches the Rock to a mile on its south side, and one and a half miles on its west side.

Now, taking the speed of the steamship, and the course she steered after 9 P. M., we find that at 9 she was five miles inside of the sixty fathom curve and nine and a half miles from Bishop's Rock, at 9.30 she was just on the inside of the fifty fathom curve and four and a half miles from the Rock. From this it can be seen that if she had headed only a half point more to the southward she would have cleared the dangers, or that a cast of the lead at 9 and another at 9.30 P. M., would have given sufficient warning of peril to a prudent navigator; but the course that was at first decided upon was adhered to, and sounding appears not to have been thought of. We learn that four officers, including the captain, were on the bridge, and that two men were on the look-out forward.

About 9.55 P. M. she must have been abreast of and close to leeward of Bishop's Rock—probably not two cables length from it—to strike Retarriere Ledge, on the course that she steered, she had to pass inside of the Rock and almost within hailing distance of it, yet they neither saw or heard anything; this seems to be incredible. The atmosphere was in a peculiarly favorable condition for the transmission of sound, she was to leeward of the bell; the regulations of the Board of Trade require the bell to be struck in foggy weather, and the light-keeper swears that it was struck. Alas! it was not heard, for even then prompt action would have saved her.

There are other circumstances in this distressing case that puzzles investigation; seamen know that as she passed close to leeward of the Rock, an appreciable change must have occurred in the force of the wind, in the character of the sea, and the smell of the rock must have been strong, particularly at low water, yet the indications were unnoticed.

What was the cause of this apparent neglect, or inability to think of the most ordinary precautionary measures, or to distinguish the presence of certain well-known signs? How are we to account for the loss of this splendid steamship, so well manned, and hitherto so skillfully handled? May we not attribute it to the operation of the causes that I have been speaking of? There cannot be any doubt about it. The three or four days of bad weather without observations, preceding the wreck, the care and perplexity of running by dead reckoning alone over a thousand miles, a position around which she was to haul in for her port, the sea crowded with inward and outward bound vessels, the currents variable in their strength and uncertain in their direction, required extraordinary vigilance on the part of her officers, the strain brought upon them, and the almost constant exposure under the custom of "watch and watch," was quite enough to use them up. The Captain was probably in a worse condition than any of his mates, for he is said to have been on deck most of the time, and this is not surprising

for he was responsible for the safety of the ship, his anxiety was the greatest, and he felt the necessity of giving his personal attention to the duties of the deck.

So that when the critical time arrived —when the perilous situation of the steamship demanded for her preservation, the exercise of the clearest judgment, and the employment of the keenest faculties, the Captain or the mates did not possess either one or the other of them, they were not in a condition equal to the emergency—their minds were clouded, their senses were blunted by overwork, exposure and insufficient sleep. If they had been in a fresh and vigorous condition of body and mind, they would not have overrun the distance, they would have reasoned out the necessity of sounding, they would have become aware of the closeness of Bishop's Rock in spite of the fog. Does any one believe that if we could have put on board of that ill-fated steamship an intelligent shipmaster and four mates, all clear headed and strong at 9 P. M., when the order to reduce the speed was given, that she would have been lost? Working from her position of three days before they would have appreciated their situation, and have at once adopted the simple remedies that were adequate to save her.

I hope that the evils of the custom of "watch and watch" are now understood, but, as great as we know them to be, it is more than probable that the Schiller would have been saved if a gun of a suitable description had been used for signals, instead of the bell on Bishop's Rock, or if it had been mounted on any convenient ledge in the immediate neighborhood and properly served, the wreck would not have happened, for its loud-mouthed warning would have been distinctly heard, even by worn and weary men, far enough off to have turned her upon her course, and thus have preserved the lives and property so sadly lost.

LIFE RAFTS.

From "The Engineer."

AMONG the numerous lessons which the details of the wreck of the Deutschland presents to our notice, there is not one more striking than that offered by the total inefficiency of the boat service in time of need. A large passenger steamer, belonging to a company whose special province it is to carry the mails and passengers between Germany and America, is stranded upon a sandbank within a few miles of a lightship, with which she is able to communicate her distress by means of signals, and yet so badly off is she in the matter of boats and the means of lowering them that but one can be launched, and that one so small that only three men are able to escape in her. There appears, however, to exist an impression that even if the boats had been sufficient in number to accommodate the whole of the crew and passengers, and had been provided with the most perfect system of lowering in existence, still it would probably have been impossible to have lowered them in safety on account of the heavy sea which was running. In our own Passenger Act it is laid down that boats shall be provided numerous enough to carry the whole of the crew and passengers; but it is manifestly impossible to hang all these boats in davits round the side of the vessel, and therefore they have to be carried stowed inboard, sometimes one within another, in places where it is almost impossible to get at them when wanted, and where they are liable to damage. It is therefore evident that to insure the safety of the passengers in case of any accident happening to the ship, it is not enough to insist on a certain number of boats being carried, but that some other means must be provided of escape from a stranded or sinking vessel in such a case as that of the Deutschland, where the practicability of launching even the boats hung in the davits is extremely doubtful.

For this purpose many different devices have been invented, out of which

some five or six have especially come before the notice of the public. The first of these is the tubular life-raft, which was originally made of some inflatable material, and of which a typical one, the Nonpareil, made the journey from America to England under sail. The United States' Commissioners who were appointed to investigate the subject, objected to the inflation on account of the time it would take, and the life-raft now adopted is made of metal, and consists of two tubes, pointed at either end, and connected by girders, and carrying air and water-tight tanks holding provisions for a week for twelve persons. These tanks are fitted between the girders, and have a screw cap both at the top and bottom, so that it is immaterial on which side the raft alights in the water. The rafts themselves are so light that four men can throw one of them into the water over the side of a vessel. A very similar apparatus was invented in 1852 by Mr. Richardson, and was called the Challenger Lifeboat. This consisted of two circular tubes of tinned iron, 2 ft. 6 in. in diameter, each tube being divided into twelve compartments. The tubes were placed 3 ft. apart, and the ends turned up and joined. The tubes were held together with iron arches, on which the grating and seats were fixed. The raft was provided with sixteen oars, as well as two lugsails, topsails, and jib. There was, however, no special contrivance for launching this raft, other than that employed for ordinary boats, which we have already pointed out as being extremely defective. Mr. John White, of Cowes, seems to have been the first to invent a method of overcoming this difficulty, by his contrivance called the lifeboat bridge. This consists in converting the bridge, which is generally used merely as a means of crossing from one side of the vessel to the other, into a lifeboat. This lifeboat is made a little longer than the breadth of the vessel, and is carried upon ways, the platform of which, being pivoted in the centre, can be lowered at either end at will by knocking down a couple of staunchions on which it rests, when, the other end being elevated, the boat is at once shot into the sea, its bilge-pieces forming the skids, which fit into the launching ways. A great advantage of this method of stowing and launching the lifeboat is, that it is not liable to be damaged, or washed away, as those hung in davits outside the ship. A plurality, too, of these bridges may be carried, according to the size of the ship, and, by a peculiar arrangement, can be turned fore-and-aft if required. A bridge boat, 40 ft. long and 10 ft. wide, will carry 125 persons, so that three of these—which can be arranged as two transverse bridges, 40 ft. apart, connected by a fore-and-aft bridge—would be capable of containing a crew of 375 persons. We understand that the Admiralty have ordered the Orontes troopship to be fitted with these bridges. Mr. H. Christie, of the Peninsular and Oriental Steamship Company, and Mr. Roper, have adapted Mr. White's method of launching to peculiar forms of life-rafts. Mr. Christie's raft, which is rectangular in form, consists of a wood framing, the spaces between which are filled with air-tight tin cases. After it is afloat, a water-tight bulwark can be formed around it, by raising a number of hatches pitted upon hinges. Mr. Roper's life-raft is very like Christie's in general construction, but his modification of White's launching ways consists of doing away with the central pivot, and lowering either end by a mechanical arrangement worked from the bridge itself; but whereas Christie's life-raft, like the American tubular rafts, is reversible, Roper's is not; and this, we must say, we consider a decided disadvantage. Both Christie's and Roper's rafts, however, labor under another disadvantage, namely, that of having but little freeboard; for if the passengers on a raft in a heavy sea are continually washed over by the sea, they are in danger of perishing by the cold before they can reach any place of safety.

A life saving vessel just invented by Mr. J. A. Stockwell certainly appears to possess some very important advantages over the three plans we have just discussed. In the first place, from its shape it is more stable and can carry more passengers than White's lifeboat; and in the second place, it has a high freeboard, and is therefore not so liable to be washed over as either Christie's or Roper's raft. It consists of a circular vessel, 20 ft. broad, and constructed of an annular cylinder 5 ft. in diameter,

round which seats are built inside. These seats, being made water-tight, can carry fresh water and provisions for the passengers. Over this annular cylinder a battened deck is fitted by means of knees, so that the sea can break up through it, and there is therefore not much fear of the vessel being capsized.

The navigating qualities of the vessel are complete, for she is provided with masts, sails, and rudder, a stem or projecting cutwater, and a drop keel which can be lowered or raised at will. The vessel would be divided into four water-tight compartments by bulkheads with sluice valves, each compartment having a separate hatchway fitted with a ventilating cap, constructed so as to admit sufficient air and at the same time prevent water from entering. Each compartment is also provided with water-tight scuttle-lights. A pump, too, is fitted to draw off any water which may get inside, communication throughout the whole vessel being maintained by means of the sluice valves in the bulkheads. On the outside of the vessel a rubbing plate of wood is worked, so that she could go alongside any ship or be boarded by a boat without danger. Life-lines are fitted round the edge 60 feet long, and carrying a cork ball at the end by which persons in the water might be saved.

One particular advantage claimed by the inventor is the fact that in this life vessel there is so vast a quantity of displacement, in proportion to the size, that it would be impossible to overload it with passengers, because there is not sufficient deck space to hold them, whereas the ordinary lifeboat, when overcrowded, is often rendered useless. The method of launching these vessels is rather peculiar. They are carried amidships raised above the deck, and placed on ways made of two angle irons forming a groove, in which the skids of the angle iron, which forms the bilge keel of the vessel when afloat, slide. Outer ways, in combination with these ways, can be slid out beyond the side of the ship, so that the life vessel can be launched clear of the side. The ways, however, instead of being straight, as in White's plan, are curved to the segment of a circle, and under the launching cradle horizontal cast iron rollers are fitted to prevent all friction or jamming in the groove of the launchways. The launch of one of these life-saving vessels from a hulk at Blackwall, some few weeks since, was perfectly successful, and we should be glad to see it further tested on actual service. We think, however, the time has arrived now when it becomes the duty of the Board of Trade to take the matter in hand. If they were to offer a premium for the best life-saving raft or vessel answering certain conditions, and to give all those competing a severe test in heavy weather, the Passenger Act might be further amended by a clause to the effect that all passenger vessels should carry a life raft of certain proportions.

HYDRAULIC EXPERIMENTS.

From "Engineering."

The typical English hydraulic engineer is the most complacent of beings; with his shelves loaded with old folios and new editions he is prepared to face the cross-examination of any awe-inspired deputation of spirited inhabitants, with the equanimity characteristic of the witness who really does know all about it, and means to speak the truth. There is little excuse required for the credulity of the members of the deputation. Works on hydraulics by long-forgotten authors can be picked up at any bookstall, and if the date happen to be somewhere about 1700, and the author as usual advances unfailing formulæ for every imaginable case, the general public may well be excused for assuming that the mine of information bearing upon hydraulic science has been so well worked that it will not repay further exploration.

Even the earnest student may for a long time remain in a happy state of ig-

norance concerning the present state of the science, but sooner or later, when dealing with some actual or hypothetical case, the truth bursts upon him that the results given by the formulæ of one cherished authority are entirely at variance with those derived from a no less venerated master, and that in short the multiplicity of his results is only limited by the number of his references. After the first disenchantment there will be little peace for him, for the further his researches are extended the more preposterous will appear the disproportion between the vast mountain of deductions and the poor little molehill of facts. Assume for the moment that our young engineer begins by conferring with his "Neville"—which is a fair sample of an English text-book on hydraulics, and serves the purpose of our illustration better than another, since a new edition has recently been called for—and assume further that he is seeking the probable mean velocity in an irrigation canal of given fall and cross section.

At the end of his volume he will find convenient Tables giving by inspection the very element he wants, in inches and hundredths of an inch. He may be curious to know to whom he is indebted for these very pleasing and conclusive results, and the text will inform him that it is to Du Buât. The name will doubtless be already familiar to our student, but if he still "asks for more," and persists in following up the trail, he may be somewhat startled to find that the date upon the Tables should be 1785, rather than 1875, since it was in the former year that the Chevalier Du Buât and the Abbé Bossut published their conclusions—which, in many instances, were based upon experiments carried out by M. Couplet, the engineer of the Versailles Water Works in the almost prehistoric period of 1732. He may possibly infer that deductions which have thus held their grounds for upwards of a century must necessarily be sound and trustworthy, but of course the inference would be entirely wrong. The tabulated velocities, though expressed in hundredths of an inch, are in reality but the wildest guesses at the actual velocities in irrigation canals of ordinary dimensions. Colonel Cautley relied upon Du Buat when he laid out the Ganges Canal, and found him but a rotten reed, for the water in every instance tore along at unexpected velocity, and erosion of the bed and destruction of works followed in its wake.

Du Buat then must be put upon the top shelf of the book-case, and it will be just as well, when the steps are there, to carry up every English work in which the name of Brüning, Girard, Bossut, Prony, Eytelwein, or D'Aubuisson, are continually recurring as authorities, against whom no action can be taken. In this general clearance Beardmore, Downing, Box, and almost every other hydraulic text-book compiled by Englishmen will, with more or less hesitation, have been shelved, and the young engineer will then be able to form a fair estimate of the contribution which his countrymen have made to the common fund of knowledge concerning the laws governing the flow of water. We think we may venture to state, without fear of contradiction, that up to the present date the science of hydraulics has not been materially extended or its progress appreciably accelerated by the labor of any English experimenter.

When M. Bazin presented his report to the Academy of Sciences in 1863, many illusions which had almost universally prevailed during the preceding century were rudely dispelled, and from the multiplicity of fresh data the science received a new impulse. Perhaps the most important of all the facts elicited was the vast and unexpected influence of what may be termed the *skin* of the channel upon the speed of the current. At the very time when these conclusive experiments were being patiently carried out by French engineers, there were not wanting two English engineers of the first rank in their profession to condemn in vigorously sarcastic terms the initiators of a series of experiments undertaken to ascertain the actual discharges of pipes made of various materials. One of these unfortunately influential critics maintained that "in an engineering point of view it was perfectly immaterial whether the surface were brick, iron, or glass, since the resistance in all instances must be the same," whilst the other one with characteristic bluntness and assurance added that "any further experiments involved a mere waste

of money." It is rather amusing to reflect that the latter gentleman was quite recently appointed a member of the committee to advise with Mr. Froude as to the experiments which should be undertaken to ascertain the resistance of steamships, for Mr. Froude's views on skin resistance are tolerably well known, and the alliance was, at least, a curious one. In the experiments referred to, the state of the copper sheathing was carefully noted by Mr. Froude, and its resistance was stated by him to be about the same as if the immersed portion of the hull were half covered with calico and half varnished—a significant refinement when it is remembered that almost every popular formula given in our text-books draws no distinction even between glass and earthwork if a pipe or channel be in question.

The results of the experiments instituted by D'Arcy, and continued by Bazin, together with the well known Mississippi investgations, afforded a grand mass of facts at which Bazin himself, Gauckler, and many others have since labored with a view to deduce a comprehensive formula which shall include every case, from a street gutter to a mighty river. The most successful of all the workers in this field are perhaps Ganguillet and Kutter, whose laboriously deduced comparative results have been reproduced in almost every other language but our own. Mr. Jackson bases some of his Tables upon Kutter, and so far as we know, that is the only instance in which the deductions of the latter have been referred to in an English work. Our own attention was first attracted to Ganguillet and Kutter's labors through a notice which appeared in the Proceedings of the Dutch Institution of Engineers. Perhaps it is not too late, even now, to induce Mr. Forest to append a full translation of the German original in an ensuing volume of the "Proceedings." Possibly some of our Indian brethren may have already translated the memoir; if our memory serves us those of Bazin and Gauckler have been republished at Roorkee though not at London.

It is only by thus taking a retrospective glance over the whole field that we can fully appreciate the precise value, and, we may venture to add, national importance of the series of hydraulic experiments which have recently been so successfully inaugurated by Captain Cunningham, R. E., of the Thomason College, Roorkee. We have seen that the contribution of Great Britain to the general store of knowledge has been perfectly contemptible and unworthy of a great nation which in its Indian irrigation works has finer opportunities for such researches than any other country on the globe. The prestige of English engineers has not even held its own in recent times, and the English element is as persistently ignored in Continental text-books, as with the foreign policy of the country in diplomatic circles before the reaction caused by the purchase of the Suez Canal shares. To recover their prestige, English engineers must pursue an equally bold policy. An exhaustive series of hydraulic experiments by the Government engineers at Roorkee would at once restore the English element to every engineering text-book on the Continent, where at present it is contemptuously ignored. Surely now that a suitable man is found in Captain Cunningham to carry out the experiments there can be no "rocks ahead." Even if we elect to be judged as a nation of shopkeepers, the experiments can be justified, as they will return the necessary outlay many times over in a few succeeding years. Lord Salisbury is half an engineer himself, and holds the reins—cannot he be induced to interest himself in the science of hydraulics?

Mr. Froude is now conducting for the Admiralty one of the most complete series of experiments ever yet undertaken by any nation. The laws governing the resistance of solids moving through water are thus in a fair way of being ascertained, and if Captain Cunningham undertakes in like manner to determine the laws governing the flow of water in large channels, we shall indeed make ample reparation for the petty filching and pilfering from our neighbors' stores in which we have hitherto indulged.

Some of the results already obtained by Captain Cunningham—as will be seen from the summary of his report—are both novel and interesting. The establishment of the principle of "unsteady motion" will clear up many anomalies;

it may, for instance, explain the differences in the mean surface velocity at the Solani Aqueduct as measured in 1874 and 1863. According to Captain Cunningham the mean surface velocity was .927 of the central velocity, whilst in the earlier experiments, if Mr. Logan be correct, the ratio was .88 only. The surface velocity curve in the Solani Aqueduct was in form a flattened ellipse, and of such regularity that the temptation to Captain Cunningham to find its equation proved irresistible. We do not see what use the equation will serve unless it be to enable us to reproduce approximately the surface velocity curve in the Solani Aqueduct, which can, of course, be better from the observations direct. We have now before us a pretty extensive assortment of surface velocity curves. In some, as in the instance of the Solani Aqueduct, the bank is tangent to the curve, but in others it is normal to the same. In one example where the cross section was very similar to that of the Solani embankment channel, the bank on one side was tangent to the curve, and on the opposite side at an angle of 45 deg. nearly. We may add that many of the curves we refer to were measured by Mr. B. T. Moore, M. A., a highly competent and scientific observer, as Captain Cunningham will readily concede, since he makes use of Mr. Moore's formulæ in the computation of his areas.

We differ then from Captain Cunningham—and we are glad to say it is the the only point on which we differ—in thinking that the fact of his surface curve being a "quartic ellipse" is an interesting result of the experiments. To us it is no more interesting or suggestive than would be the discovery that the curve of Primrose Hill was a true conchoid. We wish it were otherwise, and that some short cut could be found to the desired end, but with the diagrams before us we cannot but feel that many months' hard work have to be gone through before any generalization can be usefully attempted. It is only fair to Captain Cunningham to state that he attaches no undue importance to the discovery, and that in all probality any mathematical work is to him rather a pastime than a labor, even though the thermometer be at 120 deg. in the shade.

The Roorkee experiments afford a further confirmation of the fact that the central vertical velocity curve is approximately a parabola to within a short distance of the bottom. This truth was elecited at a very early period in the history of hydraulic science; we remember seeing it recorded in an old German tract on hydraulics formerly in Smeaton's possession, and at least 150 years old.

We are pleased to note that Captain Cunningham's preliminary report proves him to be not merely a mathematician, but a practical man who will know how far he can safely apply his facts in the development of a comprehensive theory. We are not of those who contend that every practical suggestion of a pure mathematician *must* be wrong, but we are bound to admit that too great faith in theoretical deductions unverified by direct experiments sometimes leads to an undesirable result. An amusing instance of this occurred a short time ago at a meeting of one of our scientific institutions, when the subject under discussion was the marvellous speed of one of Thorneycroft's launches. A deservedly eminent shipbuilder, well known for his persistent and able advocacy of his own theoretic deduction that to obtain a certain speed the ship must be of a certain minimum length—about five times as long as the boat under discussion—was attempting to show by a reference to the lines of the boat exhibited on a diagram hanging on the wall, that after all her performance was just as it should be. The apoplectic symptoms commonly indicative of "trying to come" what Mr. Weller termed "a kind o' quiet laugh" being alarmingly apparent in Mr. Thorneycroft's countenance, it was suddenly discovered that the diagram had accidentally been hung upside down, and that although the demonstration was progressing as well as could be wished, it of course implied the assumption that the boat traveled stern foremost.

It would have mattered little had it been otherwise. Any one who had not seen the boat at high speed might have sat quietly down and calculated her "augmented surface" and propable speed in the most confident manner, but would afterwards have been quite aghast to find that when fairly settled down to her work she just lifted her bows clear

out of the water, showing daylight under the first 6 ft. of her keel, so that as far as speed was concerned her fine razor-like cutwater might as well have been replaced by a slice off the Popoffka. All engineering history tends to prove that it is hardly safe to make the simplest theoretical deduction in hydraulic science. Before Macneill's experiments of some forty years ago it was always assumed that the resistance of a vessel moving through water would necessarily vary as the squares of the velocities. The experiments did not bear out this theoretical deduction, and so contemporary critics did not hesitate to throw over the experiments: "Only think, gentle readers!" says the *Mechanics' Magazine* of the day, "the illustrious Newton and his immortal band of followers taunted with ignorance of the first principles of philosophy by John Macneill. Is it not as if the beetle were to scoff the eagle for its blindness?" Every engineer now knows that we need not go beyond Her Majesty's navy to find resistances not merely differing slightly from the squares of their velocities, but hardly comprised with the limits of $v^{1\cdot4}$ and v^4.

An experienced experimentalist such as Captain Cunningham, will of course carefully guard against making any such rash assumption as that twice two are four. The Royal Commission on Iron Structures found when cast iron-bars were in question that 2×2 was much more like 3 than 4. Mallet ascertained that the multiplication table required similar amendment in the case of wrough-iron forgings, and we have no doubt if the ghost of Herr Musschenbrock should ever encounter Mr. Lister of the Liverpool Docks, there will be a very pretty altercation as to whether the cube of 12 is really 1728 or only 1000, when pitch pine is concerned. That two halves are equal to the whole may be an axiom sound enough for Euclid, but not so for the engineer. If, for instance, he ventured to assume that the two halves of a flat steel bar, divided longitudinally by shearing, are equal in tensile strength to the original undivided bar, the conclusion might in some instances lead to disastrous results.

In speaking thus we have no intention to depreciate the labors of mathematicians, but having gone through the mill ourselves we know—and in this Mr. Froude will bear us out—that an entire series of laborious experiments has not unfrequently had to be discarded in consequence of the neglect of some detail of theoretical insignificance. An unpractical scientist and an unscientific practioner are alike undesirable as an experimentalist. The former fixing his eyes on some distant eminence moves straight ahead until probably he is plunged overhead in a morass or quicksand; the latter picks his steps painfully and cautiously enough, but before long unknowingly presents his back to the desired goal. Captain Cunningham we feel sure will avoid both evils, and take the shortest practical route to the point at which he aims.

A very complete organization will necessarily be required if the hydraulic experiments now commenced be carried on to a fitting completion, and doubtless the best practical step would be to put Captain Cunningham in communication with Mr. Froude. We think also that some of Mr. Moore's ingenious instruments, notably the self-recording current direction indicator, one of which is with the Artic expedition, might in Captain Cunningham's hands lead to the development of some unexpected and valuable results.

In conclusion we can assure Captain Cunningham that his labors will be watched with interest by engineers at home, who are glad to find him following thus worthily in the steps of his father, General Cunningham, now at the head of the Archæological Survey of India, and of his uncle, Colonel Cunningham, whose loss the literary world has within the last few weeks had cause to deplore.

A Pittsburg correspondent of the *Railway World* writes that Messrs. Lewis, Bailey, Dalzell & Co., Messrs. Spang, Chalfant & Co., and Messrs. Graff, Bennett & &o., have bought one of the Butler County gas wells, and are arranging to convey the gas in a sixteen inch tube a distance of seventeen miles to their works, to be used instead of coal. They claim that it will enable them to produce iron at a rate that will give them an advantage over all eastern producers.

EXPERIMENTS ON THE MOVEMENT OF AIR IN PNEUMATIC TUBES.

By M. CHARLES BONTEMPS, Engineer in the French Postal Service.

From "The Engineer."

The establishment of the pneumatic system in Paris afforded the author an opportunity of investigating the movement of air in the tubes. For this purpose a system of registration was adopted, electric indicators, connected by wires with chronograph, being placed at intervals along the experimental tube. Each indicator consisted of a box, containing two cams controlled by springs, and a projecting stud. At the spot where the box was attached to the tube, a hole was drilled in the latter, and the box was placed in such a position that the stud entered the hole in the tube, its rounded end projecting slightly beyond the inner surface. The carrier in transit struck the stud, which actuated the cams, and the electric circuit being thereby closed, a mark was made upon the chronograph. This instrument consisted of a train of clockwork giving motion to a cylinder, round which was wrapped a sheet of smoked paper. Parallel to the axis of the cylinder there was a carriage bearing two electric magnets, one in connection with the indicator in the tube, and the other with a second beating electric clock. Each armature was terminated by a fine point, which reproduced on the smoked paper the oscillations of the palette. Motion was given to the carriage by a cord and weight. The carrier, in passing along the tube, closed the circuit on striking the studs, producing a deflection in the straight line traced by one point on the smoked paper. The other point produced a regular indented line parallel to the former, each indentation representing one second. These lines alternated with one another. As soon as the observation was taken the smoked paper was removed, and the surface was fixed by placing it in a solution of gum. The moment of commencing the experiment was electrically noted by a commutator attached to the cock between the reservoir and the tube.

The experimental tube had a total length of 6704 ft. 8 in. It was made of wrought iron 2.52 in. in diameter, in lengths of 16 ft., 4¾ in., and connected the central station at Rue de Grenelle, St. Germain, with that of the Place du Theatre Français. It was practically level, with a few curves of large radius; and was laid partly in the ground, partly in subways.

Five indicators were employed; their positions, distances from the Rue de Grenelle, and the periods occupied in the transit of the carriers, &c., being as follows:

Name of Station.....	0 Terminal Station, Rue de Grenelle.	1 Cellar, Rue de Grenelle.	2 Solferino, No. 1.	3 Solferino, No. 2.	4 Rue de Rivoli.	5 Theatre Français.
Distances from Commencement.....	0	ft. in. 215 6⅝	ft. in. 1659 8	ft. in. 2628 3 1/16	ft. in. 5413 1¼	ft. in. 6704 8
Distances between two Indicators.....	0	215 6⅝	1444 2 1/16	968 9 1/16	2784 9¼	1291 5 1/16
Times of transit.....	0	2.3 secs.	30 secs.	57 secs.	136 secs.	167 secs.
Time between two Indicators.....	0	2.3 secs.	27.7 secs.	27 secs.	79 secs.	31 secs.
Mean speed per second....	0	ft. in. 91 10⅜	ft. in. 49 2 3/16	ft. in. 35 7⅛	ft. in. 35 1¼	ft. in. 42 8

The experiments showed that at the moment when transmission commenced the gauge index first fell, and then rose till it reached a fixed point, always low-

er than the initial pressure. Also that the speed of the carrier gradually reached a uniform rate, the slight increase at the end of the journey having been due to a secondary cause not affecting the result obtained.

In other experiments the action of two carriers having a common movement in the tube was examined. The first carrier was stopped in the tube, after a transit of six seconds; the second was then despatched, and from the period of contact of each with the studs, the following data were obtained:

Position of Indicator.	Passage of 1st Carrier.	Passage of 2d Carrier.
	Secs.	Secs.
0. Rue de Grenelle..	——	0
1. Cellar " ..	——	2.5
2. Solferino No. 1..	26.5	32.0
3. Solferino No. 2..	54.0	60.3
4. Rue de Rivoli ...	133.5	139.5
5. Theatre Français	165.5	171.25

From these figures the author deduced: 1. That the time occupied by each piston in traversing the interval between two successive indicators closely approximated, which showed that the two pistons required similar periods to traverse similar distances. 2. That two pistons which had acquired their normal distance apart, preserved it throughout the whole journey. 3. That the progress of the carrier last introduced was independent of the initial position of the first. From No. 2 it followed that the density of the air was constant from the commencement to the end of the journey as soon as uniform movement in the tube was established.

The periods required by the carriers to traverse the tube between two indications, with different pressures, were as follows:

From Rue de Grenelle to	1. Pressure. 19.685 in.	2. Pressure. 17.716 in.	3. Pressure. 14.960 in.
	Secs.	Secs.	Secs.
Solferino, No. 2...	57	62½	73
Theatre Français..	167	178½	208

The respective periods of contact with each indicator were 2.9 secs., 2.8 secs., and 2.9 secs. This practical identity was not accidental, but followed the general law, that the ratio of the periods of transit over two equal distances chosen arbitrarily on the line was, in the uniform period state, independent of the pressures.

BRITISH ALKALI ACTS—ELEVENTH ANNUAL REPORT BY THE INSPECTOR.

The Alkali Act of 1863, after eleven years of solitary struggle with noxious gases, receives assistance from the Act of 1874, and now begins in a small degree a more vigilant, and it is to be hoped a more useful life.

I have little to do but to sum up the work of the past, and I have already done so much towards this that the summary must be short. It is such a frequent question in my mind, what is the Act doing for the good of the public? and, I may add, what are the inspectors doing? that I ought to have the replies ready; but I doubt if it is quite possible to make them with full satisfaction to all. If it is asked whether we have done the work set us to do, then I answer by the reports that we have done so; but if it be asked whether we have caused vegetation to rise up where it was not before, if we have produced or allowed to be produced fruit where fruit would not previously grow, then I am afraid we must answer, No. If, however, we are asked whether we have prevented the destruction of vegetation where otherwise it would have been destroyed, then we may safely answer, Yes. It was not our duty to cause crops to

grow, it was our duty to cause the works under our charge to send out not more than five per cent. of muriatic acid. This certainly has been accomplished in the full sense. Gas has occasionally escaped from nearly every work to too great an extent for a short time, but it has been stopped, and the consequence is that the great torrents which at one time rolled over the country are not now to be found. This sounds very well, but vegetation is destroyed without torrents. A gentle flow from a chimney or other part of a work may scarcely annoy us much, and yet in time it may cause destruction to trees and to all perennial plants; whilst a little more, causing still only occasional inconvenience, may destroy annuals and obliterate grass. We must then, in order to obtain a flourishing vegetation, avoid even small portions of gas; and the question remains, how small is the smallest amount in the air that will do injury. It is not safe to allow even as much of sulphur gases as we have in Manchester and similar large towns if we consider vegetation alone.

If more is allowed, then trees disappear. In these small quantities the effects of sulphurous acid and sulphuric will probably be nearly the same. Different opinions are given on this subject. My opinion is that sulphuric acid does most harm at once, but it may be that in the long run there may be more harm done by sulphurous acid first by acting as a deoxydizer, and next by acting, if we may so speak, as sulphuric acid into which it is converted. Of this, however, I know no evidence; but the perception of sulphurous acid being keener and more immediate may favor the supposition, and a not uncommon belief that it does more harm may be founded on better evidence than I can find for myself.

Allowing for the time that when the quantities are small the relative activities of the gases approach each other, I am inclined to go back to a proposal made some time ago in a former report, that the condition of the air of a place ought to be estimated before allowing a chemical work to be established.

If an atmosphere is made to contain 1,000 grains of sulphuric acid per million cubic feet when there are ten works in the community, say in half a square mile or any other space, it cannot be expected to contain air of the same amount of purity when there are eleven works in the space, unless the eleventh work gives out no emanation whatever. But if this absolute purity is not found in the ten, why should it be expected in the eleventh? The expectation is simply irrational; and as places increase in manufacturing industry the air becomes less pure unless the processes are improved. If the processes do not improve the community must either prevent increase or suffer more inconvenience by increase.

This reasoning is childishly simple, but it is not the less needful to write it down, since the complaints continually increase with the increase of works, and the increase of works is not only permitted, but for national as well as private purposes desired.

We have not yet looked the matter with the greatest fullnes in the face. If we are determined to keep towns to a certain standard of purity we must make the standard: if we keep only the works themselves to a standard, then the number of works must not increase, for then the relation of the air of the town to the standard would be altered. It has been shown, as I believe, in my reports, that a chemical standard may with great ease be obtained, but it is one which the community does not fully appreciate, and it is left in the hands of few; but there is one standard known to all, and that is vegetation. This is the most watchful of all inspectors, and the most accurate, and it only requires to be brought into scientific order to be made suitable for constant reference.

It may be taken for granted that where trees flourish, there also man is uninjured by acids such as are given out by chemical works. I say it may be taken for granted at present, but it is only because we know little, and it may be that the influences are hurtful to some extent to men whenever trees suffer. But this we know, that trees may die in an atmosphere tainted by the acids alluded to when men generally are not sensible of inconvenience. The effect on vegetation, therefore, is more striking than upon human beings. The

number of circumstances that influence the death rate is great.

However, I wish to say that we have the matter in our hands; we can estimate the condition of an atmosphere in its relation to acids by the vegetation, but we can estimate it also by chemical methods: and if we allow it to go out of order we must not only blame the works, but ourselves who allowed the works; and if we cannot prevent them we must either submit or fix the standard for them. The standard for the works is not of so much importance as the standard for the district, so that at present our acts are in a very infantile state. It is little matter how much is given out by any work if the district is not injured, and it might happen, when the work was small, that a great proportion would be after all a trifle, but when many works exist a small proportion would of itself be a great evil. I have reasoned more or less in this way repeatedly, but I know that we are not quite ready for legislation embodying all these ideas, we shall probably be prepared before that time comes when our works decay, and the desire to keep them in order shall give way to the hope of keeping them in existence. The progress of the community and of chemical manufactures must go on together, and it may be considered certain that prosperity will endure more pressure, since prosperous men are more ready to complain and more able also to remove cause of complaint.

The results of inspection of No. 1 District as sent by Mr. Fletcher are very satisfactory, although there have been considerable complaints. The works are in many cases unfortunately situated in relation to trees and pleasure grounds, and it is difficult to say what the result of the increased power of attention will be. However, if the manufactures increase in numbers and in magnitude as they have done, it will perhaps not be possible to do more than to keep pace with them and prevent more mischief. I hope this state will be reached. If there should be a difficulty, the great question, who gains most, the community or the individual, will to a certainty be settled by the greater power, but in doing this the rights of the smaller cannot be forgotten. I need not repeat what I have before said on damages.

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Some successful efforts have lately been made in St. Helen's to improve the appliances for condensing muriatic acid, and preventing its escape. The principal are Mr. Gamble's salt-cake furnace, the introduction of thin glass pipes for the conveyance of hot acid gases, and the use of improved hoods over the charging doors of salt-cake furnaces.

Mr. Gamble's salt-cake furnace is a close roaster or muffle furnace heated by gas, and so arranged that the pressure in the combustion spaces is greater than that inside the muffle or inner chamber where the salt-cake is roasted. The consequence of this is, that if there are any cracks or leaky places, either in the middle arch or in the bed, the passage of air is not from the roasting bed into the fire flues and thence to the chimney, but from the fire flues to the roasting bed and thence to the muriatic acid condensers. By careful adjustment of the damper in the flue leading to the chimney the pressures on the inside and on the outside of the middle arch can be made so nearly equal that there is very little passage of gas in either direction, even if the brickwork is somewhat leaky. This increased pressure in the combustion chambers of the furnace is kept up by admitting the gas under pressure from a "producer" as commonly constructed, and by admitting the air necessary for its combustion through a nest of vertical iron pipes nine feet long. These are warmed by the waste heat from the furnace. In this way a saving of heat is effected, and the ascending force of a nine-feet column of hot air is gained.

Mr. Gamble has erected three of these furnaces; one of them has been at work for two years, and has required no repairs during that time.

The expense of fuel is said to be the same as in the case of a close furnace fired direct.

The thin glass pipes for conveying hot muriatic acid gas have been well tried in St. Helen's, and show many advantages over the earthenware ones, in that they do not crack so readily with the heat, and cool the gases more effectually. They have been used for conveying gas

both from the decomposing pots and from the close roasters.

One range that has been at work for many months, was exposed during the winter to both snow and rain, there was no roof over it. Experiments have been made to ascertain the rate of cooling per yard of pipe. Two ranges of pipes each 100 yards long were examined, the temperature at the hot end was 310°, that at the cooler end 134° Fahrenheit, showing that the cooling went on at the rate of 0.59° Fahrenheit per foot. This would depend on the quantity of gas passing, of course. The temperature of the day was 45°. The quantity of acid condensing in the pipes was not great, when however a fine jet of water was introduced at the hot end, two-thirds of the acid was condensed."

Mr. Kynaston of St. Helen's says: "My experience with the glass pipes for the conveyance of hydrochloric acid has been very satisfactory. We use them for the conveyance of both pot and roaster gas from close furnaces, and they will stand the alternations of heating and cooling better than any earthenware pipes we have tried, whilst their cost is not greater per yard than earthenware pipes of the best quality. We have now at work several lengths of pipe which have been in almost constant use since May last. I believe that glass pipes will be eventually used to the exclusion of all others for the horizontal portion of the range for conveying muriatic acid from close furnaces."

Mr. Hazlehurst has not had so much experience with them, but has the same opinion, mentioning that the fixing must be made carefully to prevent breakage. My own observations are most favorable to them, and as every chemist, and we may say every person knows, glass will not allow the passage of fumes; and when earthenware pipes are found fuming along the whole length, these glass pipes are found without a trace of gas around them. The junctions, however, may leak exactly as the junctions of the other pipes. These junctions can be cured when the pipes themselves cannot.

Hoods—At the Bridgewater works St. Helen's, large wooden hoods have been erected over the charging doors of the salt-cake furnaces. A flue leads from the top of the hood to a smoke culvert, so that any escaping vapor is drawn to the chimney. These hoods are much larger than those which have been used before, they measure 14 feet by 7 feet at the bottom, and are 18 feet high. The flue to draw off the vapor from the point of the conical hood is 18 inches square. They answer the purpose much better than the smaller hoods which have hitherto been tried, and keep the sheds very free from muriatic acid gas. The quantity of acid which rises from a charge of salt-cake is however very small when spoken of as a per-centage of that originally contained in the salt. Since the erection of these hoods Mr. Fletcher has measured it, and found it to be on one occasion $\frac{1}{15}$ of one per cent., at another time it was $\frac{1}{75}$ of a per cent.

Hoods hitherto have been of little value for want simply of magnitude, and we must thank Mr. Leather for this improvement. His hoods have one fault, but it is more of principle than practice. The draught from the hoods is into the chimney, it would be better into the condenser. The current however of gas is so small that it does not affect the chimney perceptibly, although it would be disagreeable to those standing near at the time of its escape from the furnace into the air at the usual level of the human head.

ESTIMATION OF NITRIC ACID.

The removal of the acids from the air before it escapes from the chambers, is of the highest importance to the manufacture, and it is equally so to the public. The use of Gay Lussac's tower and other precautions seem to retain the nitrous fumes to an extent which in many cases must be called quite as much as can be desired. The best mode of estimating the escape has been considered, and many experiments tried. A list follows of results after collecting in water and in bi-chromate of potash. When the amounts are small these methods may be sufficient, and if taken out by the flexible aspirator and skaken along with the solution, there is no important loss, otherwise it is appreciable; and when the density of the fumes is great, the loss is also great, and such as would render the analyses of little value.

The method which hitherto has proved itself the most rapid is by the use of peroxyde of hydrogen.

When red nitrous fumes are passed into it they disappear at once, care being taken that the amount of peroxyde is sufficient, and the speed of passage not too great. If the amount should be very great, the use of the flexible aspirator, and of shaking, a method so frequently spoken of, finishes the process of absorption in a few seconds. Permanganates will act also, but they introduce colored bodies.

When the amount of nitrous gases is examined in this way, the estimation is the same of course as for nitric acid, in other words the oxydes are converted into the higher oxyde. I have no results from works by the peroxyde of hydrogen process.

It is important to have a ready mode of deciding the amount of this acid, and many have been tried. It is necessary for us that the manipulation should not be great The indigo process I had given up as a failure in very early days, but it was again tried at the wish of my assistant, Mr. Gillespie, with the following results. The presence of organic matter destroys all confidence, and in chimneys there is usually sufficient from the coal.

The nitric acid was reduced by means of zinc and sulphuric acid ; the sulphuric acid, diluted, was added in portions at a time, so that a brisk evolution of hydrogen was given off for about two hours. The ammonia formed was determined by Nessler's solution, without distillation, after making a portion of the acid liquid somewhat alkaline with caustic soda, and removing the precipitated zinc oxyde. The amount of ammonia in the re-agents used must be taken into account by making a blank experiment with them.

This may be a satisfactory process for rapid work, but it is not exact. When great exactness is required the ammonia must be distilled. An alkaline process, such as the Schulze-Wanklyn method, with aluminum is capable of wonderful refinement, but takes longer time than the above.

The oxydes of nitrogen between the dioxyde and nitric acid oxydize sulphurous acid rapidly, nitric acid does not ; indeed in some cases it appears to preserve sulphurous acid.

APPARATUS FOR CONDENSATION.

It is perhaps time for us to have some new ideas regarding condensation, and I expected this year to report some progress that might be important. There are, however, a few indications to be given of the character of the progress attempted that may be of value. The patent of Messrs. Newall and Bowman has been alluded to, and I should have described it more fully had it been carried out to its full extent. Instead of high tanks, the owners employ low chambers filled with a fine spray of water or weak acid ; when the gas is cooled to a certain extent it passes through tubes from the first to the second chamber as in the plan. The advantage of this is the great exposure to the air and the rapid cooling, as well as the rapid admixture of the gas with water. I hope soon to have a thorough account of its results, but I said so on a previous occasion.

The first act will be to generate heat as usual, the thorough cooling in one vessel could not be attained with sufficient rapidity without adding more water than is desired, for this reason some of the gas is passed into a second vessel, becoming cooled partly on the way, and is subjected to another spray. The final act seems best performed in a condenser filled with coke, bricks, or some substances which expose a large surface, the last form of the vapor seeming to require this agency as chemists well know.

The cooling of the gases presents many advantages. We then have only the heat of combination with water to deal with, and that is not subject to variations except so far as the acid varies in the amount of water, but the variation will be very regular. Another idea, however, is that it may be better to add the water of condensation to the warm gases, because then more heat will be generated at a time and the greater the amount of heat the more rapid will be the cooling. The objection to this may be that a high heat will weaken the acid, sending off a large portion of gas to be added to water at another stage ; if however, only a portion of the water were added at a time the great heat would not be attained. This latter method would seem to be the idea carried out in the plans shown. If the heat could be got rid of in tubes instead

of in towers or cisterns the speed would be still greater, and the use of tubes seems to be the favorite method adopted when the Hargreave's process of decomposing salt is employed. This process consists in decomposing common salt by means of the sulphurous acid direct from the sulphur kilns or burners, along with a certain amount of air and vapor of water. The heat is great as the whole of that caused by the combustion of the sulphur and iron of the iron pyrites, as well as that of combination must pass together through the condensing apparatus. This large amount of heat has caused a demand for more cooling, and this is found to be attained by numerous tubes. I have obtained a photograph of those at the Runcorn Soap and Alkali works. There are two long stone cisterns connected by 18 sets of tubes, each set going up and down five times, so that the cooling surface is very large indeed. The gases go finally through the standing tower. In order to assist the gases through this long series a Root's blower is used which works in the acid at a heat high enough to prevent its destruction or at least its rapid wear. The length of cooling pipes used in the manufacture of acid generally, may be said to be constantly increasing, and although I have mentioned this system of pipes in connection with the Hargreave's process, I must not forget that one set has been in action some years at Mr. Gamble's and one at the Netham works, having been erected by Mr. Philip Worsley, for the ordinary purpose of condensation where common salt is decomposed.

A plan by J. Mather has lately been proposed; it consists of a series of troughs. Air which has been compressed, and then I suppose allowed to cool to the ordinary temperature of the atmosphere, is driven in by the tubes marked H. At the same time it raises the water or weak acid into fine spray, as it is driven in by violence. The apparatus is said to be used either vertically or horizontally. I do not sufficiently know the amount of pressure and its influence, as the apparatus is not in use, so as to be able to judge of the cooling on one hand and the resistance on the other, but, so far as I know, the idea of sending in cold so as to absorb at once the heat of combination is a novel one, and its success must entirely depend on the price of cold. I have made inquiries into this subject, but the question seems still unsettled which is the best cooling apparatus. So far, however, as I can find, the cooling by expansion does not promise to be cheap. The range from the ordinary temperature to boiling, say 60 to 212 is 152° F., or from 15°.5 to 100° C. is 84.5, whilst the range from 60 F. to freezing, or 15°.5 to freezing including the latent heat is 170° or 95° C. It will therefore take not far from a ton of ice to absorb the heat required to raise the same amount of water to boiling. The manufacture of nearly a ton of ice, or its equivalent in cold, so to speak, by the expanding engine would be a rather troublesome process if as I suppose something like half the heat of combination must be got rid of artificially. Even that is enough from a ton of salt to raise the temperature of a ton and a half of water from 60 to boiling. There is also the heat of the gas besides. It may also be remembered that increase of air is not in favor of condensation of gases for mechanical reasons.

As to cooling before condensation, a great deal has been said on this point. I must mention a plan by Mr. Steele at Runcorn; he passes the tubes through a cistern of water and the rapidity of cooling is great. It is found that 24 feet lower the temperature of the gas of one furnace from 478° F. to 362° or 116° F. = 64.4° C., or 4.5° F., or 2.8° C. per foot.

There can be no doubt that cooling is best effected in narrow vessels or channels, with large external surfaces in proportion to the capacity, but when I bring forward these facts, I do not at all mean to say that the towers have failed. Indeed, I know no better condensation than is made quietly in one tower for a pan and furnace, but the work done is not excessive and the cooling of the tower is therefore sufficient. An increase in the quantity, efficiency, or rapidity of the work demands new appliances.

Let us take an example of actual condensation with ordinary towers. In a work at St. Helens 11 cwt. of salt are used every two hours = 132 cwt. in 24 hours, and containing, as it is not quite pure, 57.7 per cent. in 76.164 cwt. of

dry HCl=253.88 cwt. or 12.694 tons of acid of 30 per cent. and 1.155 specific gravity.

A stone tank is near the pan and roaster, into which some acid falls at 46° C.; about ⅓rd cubic foot of 1.42 specific gravity, when cool is found here. It is very impure. No. 2 tank contains 48.1 cubic feet of acid of 31 per cent. and 32° C., or 1.543 tons.

The tower is reached by acid gas of 60° C. or 140° F., and from it, after water of the ordinary temperature is supplied, there are about 400 cubic feet of acid of 29 per cent. and of a temperature of 54.5° C.

It is seen that even if the temperature is reduced to 60° C. the amount condensed without adding water is only one-eighth of the whole, and the temperature must rise in the tower higher than 54.5°, but how much in the centre is not clear, probably only a few degrees above the issuing acid.

The gases were found to contain grains in a cubic foot—

	Water.	Acid.	Grammes per C. Met. Water.	Acid.
From the pot	484.72	660.69	1109.27	1511.9
From the roaster	19.38	133.07	44.35	304.5
From the outlet to tower	22.66	128.20	51.86	293.4

In another experiment :

	Water.	Hydrochloric acid.		
From the pot	63.80	56.66	146.00	129.66
From the roaster	.64	28.60	1.46	65.45
From the outlet to tower	7.10	16.53	16.25	37.83
Temperature of gas from pot		180° C.		
Temperature of gas from furnace		315° C.		
Temperature of gas from entering tower		60° C.		

It is clear that the smallness of the condensation is not due to the want of cooling only, if at all, but to the want of water. The roaster vapor in the first experiment has only 12.6 per cent. of water vapor instead of 70, and the outlet has almost the same, viz. 15 per cent. The supply of water is given in the tower, and the heat of combination and condensation are envolved there. We should expect every experiment to differ according to the state of the charge.

This points to modes of condensing alluded to where the large tower which does not so easily part with its heat is displaced by small vessels.

One may believe it quite possible to get rid of the heat of combination much earlier by still smaller vessels than any one uses, and more frequent supply of water, or one may suppose only the tubes to be used and supplied at frequent intervals with moisture. In some such direction we must seek for condensation in a shorter space and in a more inexpensive as well as effective manner.

At the same time it must be confessed that the success is not to be had in a moment. It will be seen that the amount of water along with the gas is not quite regular ; this might be got over as it is always small, and must be from the very nature of the usual process. The tower in its capacious interior equalizes all by holding water and gas for some time together, and it would seem that a tower must finish the process so far as we know. This irregularity and consequent difficulties do not occur with the Hargreaves process.

EFFECT OF ACID VAPORS ON HEALTH.

In my last report I gave a chapter on the effect of gases from alkali works on human health, and after saying that the information was meagre but all I could find, I came to the conclusion, sufficiently temperate in expression.

"I should infer from this that zymotic diseases and lung diseases are not removed by the gases of chemical works, but that none of the places exposed to them are so much affected (*i.e.*, by these diseases) as the dense parts of the cities."

The general conclusion is that gases from chemical works are hurtful to the health, but are neither the worst causes as some have supposed on the one hand, nor are they the disinfecting or curative agents which some have supposed on the other.

I shall not go into details of objections to my conclusions because I think this is not a proper place to maintain public discussions, and so little bigotry have I in the matter, that I do not care if I am proved to be wrong by a large amount of information than I have obtained. I should by no means think this a disgrace, because the subject cannot be begun with correct conclusions but must gradually unfold itself, probably with many rises and falls. I grant that it may be wrong to draw any very decided inference from the statistics of South Shields, unless manipulated with great exactness. This process, however, produces in itself frequent uncertainties and suspicions, and I do not enter upon it. I can, however, readily believe that the population of a seaport is exceedingly difficult to bring under exact rule. With the full belief that I shall again be held as bringing out meagre statistics, I shall produce some from a district of all others most exposed to the fumes from alkali works.

DEATHS IN 1,000 DEATHS AT WIDNES FOR FIVE YEARS ENDING SEPTEMBER 12TH, 1873, AND IN ALL ENGLAND 1869–1872.

	Widnes.		England.			
	Five Years.	In 1872.	1872.	1869.	1870.	1871.
Phthisis	64.46	65	107.619	106.422	106.106	104.481
Bronchitis	78.62	53	87.489	89.346	91.369	93 342
Laryngitis	6.3	6	3.135	3.374	3.405	3.191
Pneumonia	95.12	100	41.505	51.401	46.427	44.567
Asthma	0.23	6	6.100	7.541	7.619	6.884
Lung disease	15.70	9	9.964	10.009	9.959	10.359
Scarlet fever and scarlatina	61.29	59	24.397	56.279	63.672	36.344
Whooping cough	14.94	15	28.253	22.327	23.285	20.279
Small-pox	4.72	9.4	39.074	3.186	5.126	45.268
Total	335.71	322.4	317.536	349.885	356.968	364.715

Now I do not care to draw conclusions wholesale, but two points strike me as interesting. 1st. That bronchitis cannot be considered high, being less than in 1872 for all England, which year had not a very large amount. 2d. That scarlet fever, which gases might be supposed to disinfect, is very high whilst whooping cough, which the gases when strong are supposed to cure, is low. As to the general health I do not think five years of such a population as that of Widnes to be a standard for reasoning from; it is frequently changing; there are many young people moving to it for work, or leaving when work is slack, and one can best judge from the character of the complaints incident to the place from those diseases which attack people who are not mere weaklings.

I ought not to forget that my colleagues, inspectors for the separate district, have a right to have their opinions recorded. Mr. Fletcher tells me that about two years after the passing of the Act, two proprietors, or their agents, showed him trees that had been marked for felling, but from their revivel were retained, and in one of the districts at least are now flourishing. He mentions also a large estate which he considers to have been saved by the Act, and it certainly is my opinion that the trees must have gone to destruction long ago had the Act not existed, even without the increase of works, but most certainly with it. Mr. Fletcher says also that the farmers round St. Helens have not complained of muriatic acid lately, but the chief complaints have been caused by sulphuretted hydrogen. I am not disposed to speak quite so favorably as he does to acid, but on one point I fully agree, that "people have forgotten how bad it was before the passing of the Act of 1863."

This Report takes no notice of anything done under the Act of 1874. That Act has caused several fresh plans to grow up; some only have been alluded to. A plan for drawing all the gases from close roasters through a condensing system with lime to finish with, a fan being the agent at the extremity, and quite free from any of the gases, is one that I am desirous of seeing tried.

THE SALTPETRE DEPOSITS OF PERU.

From "Journal of the Society of Arts."

The country wherein lies the industry I propose to describe in this paper, is situated on the West Coast of South America, and belongs to that part known as the Costa Seca or Dry Coast, being the slip of land comprised between the 4th and 40th degrees S. latitude, and which, measured from the River Tumbez, the Southern boundary of the republic of Equador, to Valdivia in Chile, embraces, within a length of over 2,400 miles, the entire seaboard of Peru, Bolivia, and part of Chile. Over this considerable extent of sea coast no rain falls to modify the parched appearance of the soil, and no humidity is obtained from the heavens beyond that acquired from the condensation of the fogs which envelope the coast during the winter months. With the rare exception of a shower of rain occurring once or twice in the year, the cultivator is dependent upon the scanty supply of water afforded by the rivers which derive their origin from the rains and snows which fall but moderately on the western slopes of the lofty Cordilleras. Thus the coast can be briefly described as consisting of a succession of valleys of great fertility, separated by arid wastes of high ground of immense extent.

The section with which I am at present dealing lies at the southern extremity of Peru, and though saltpetre exists in small quantities in Bolivia, up to now it has only been worked in the former country, in the province of Tarapacca, perhaps more familiarly known as the district lying inland of the ports of Patillos, Iquique, Mexillones, and Pisagua. The coast between these ports presents seawards a precipitous front, with its cliffs rising to a height of from 1,000 to 3,000 feet from the water. These cliffs have but little slope; therefore, all road approaches are traced in a diagonal direction upon their face, or ascended by a series of reversing inclined planes, of exceeding steepness, and perilous to the mules performing the transport service.

From the summit of the coast cliffs the land rises with nearly an uniform ascent, proving to be, by the construction of the Iquique and La Noria Railway, after deducting for the deviations of the latter, a general inclination of 50′ until it reaches an elevated plateau known by the name of Pampa de Tamarugal. This pampa, or extensive plain, is situated at an elevation of 3,440 feet on its western side, and, extending southwards and northwards, measures about 300 miles in length, and from 30 to 60 miles in breadth. The surface is perfectly smooth, and appears level to the eye, but in reality it rises slightly in an easterly direction towards the Cordillera. Its surface is covered in some places by a cap of alluvial soil, but more generally consists of a finely granulated sand, which is raised by the slightest breath, and by a heavy wind is carried over the plains in broad thick clouds, which obscure the horizon, and bilnd the traveler with their dust. On still days curious conical-shaped clouds, resembling water-spouts, may be seen rising up in all parts of the plain, produced no doubt by the rotary motion which must occur at the meeting of two opposing currents of air. Then a tremulous motion is observed when the eye scans the horizon, and this is caused by the ascent and descent at one and the same time of layers of air at different temperatures—the cool coming down, the warm going up. At different points the horizon is broken by patches of tree; these trees are called "algarovas," and their wood is hard and

brown, not unlike English oak. They seldom grow in this locality to any considerable height. The deposit of roots belonging to this tree, to be found nearly all over the pampa, indicate the existence in former days of an immense forest, and the traditions of the place explain that formerly wood was the only fuel used in the reduction of the saltpetre and other minerals in which the province abounds. The algarova requires but little moisture, and subsists on the humidity which it absorbs from the atmosphere.

The mineral containing saltpetre is called "caliche." Caliche generally lies at depths of from one to ten yards below the surface, and sometimes resembles in appearance loaf sugar, and at others rock sulphur; and again it appears white, crossed with bluish veins. Its gravity varies from that of common salt to sandstone (2.41 average), according to the amount and nature of earthy matters it may be allied with. The nitrate portion dissolves freely in boiling water, leaving behind as a residuum the earthy substances. The custom is to boil it at a temperature of from 220 to 240 degrees Fahrenheit. This valuable mineral is found beneath a covering of calcareous earth, generally assuming the appearance of half-formed sandstone, when it is serviceable for building purposes. A shaft, or hole, sufficiently wide to permit of the passage of a man, is sunk through this cap as far as the under side of the caliche, at which point the underlying earth is dug out in a circle for several feet. The chamber thus formed is charged with gunpowder (manufactured in the district), and on being fired the result is to disengage and throw up to the surface the subterranean caliche, which is picked out by hand and stacked up in heaps at some convenient point, whence it is conveyed in carts, capable of holding about a couple of tons, to the "oficina," or manufactory. Considerable skill is required in selecting the points where to begin mining operations, and it frequently occurs that large sums of money are paid for lands which on being worked prove to be worthless, either on account of the scarcity of the caliche, its bad quality, or its great depth beneath the surface. These losses are sustained on account of the difficulty sometimes experienced of obtaining labor or tools in a country so inhospitable in its resources, and possessing no real indigenous population.

At the manufactory the caliche is broken up, either by hand labor or by steam crushers, into cubes capable of passing through a 1½ inch ring. Blake's patent crusher, manufactured by Messrs. Marsden, of Leeds, has of late years been used in several manufactories, and would, I have no doubt, be more generally employed for this purpose, were the body of the machine made in sections to facilitate its transport, instead of being in one massive block weighing several tons.

In the old method of extracting the nitrate from the caliche, the broken caliche is shoveled into the boiling pan, which is placed over a fire. After from six to eight hours' boiling in a liquid composed of fresh water and the liquid remainder of a former boil—called *aqua vieja*, or "old water"—the nitrate of the caliche is dissolved and forms part of the solution, which by means of a ladle is transferred to a pan, where it deposits its nitrate. In this process the caliche is boiled at a low temperature, and the salt is supposed to remain in the refuse. Great waste attends the operation of dissolving at a low temperature, which can not well be avoided by using the direct fire employed at the *paradas*, and it is estimated that in some cases some 30 per cent. of nitrate is thrown away with the refuse, or, as it is called there, *ripia*. The water is lifted up from wells in buckets attached to ropes working round a drum, which is placed on a vertical shaft and made to revolve by a mule drawing round its circumference. Thus no steam power is employed in this process. The increasing demand for nitrate caused the introduction of improved plant for its elaboration, and now all the important manufactories are worked by steam-power.

The improved form of *cachucha*, or boiling-tank, is either opened or closed, and the heating agency is steam, introduced at the bottom of the tank by means of a steam-coil. The coil is usually placed beneath a perforated false bottom, thereby allowing the heated vapor to circulate through the caliche lying immediately above. Sometimes an

additional coil is run directly through the caliche.

Great diversity of opinion exists among saltpetre manufacturers upon the most economical form of cachucha. Some advocate the closed cachucha, which in every respect may be compared to a steam chest, because they maintain that, the steam being enclosed, there is no waste of heat, and consequently an economy is effected in coal. Their opponents assert that the steam in the cachucha condenses, and thereby weakens the solution, and that it prevents a most important operation—the stirring up of the matter during the boiling. On the other hand, the open cachucha allows the steam which has passed through the caliche, and done its duty, to escape into the air, and enables the attendants, during the entire boiling, to constantly turn over the caliche, thereby enabling the heat to penetrate into every crevice of the mass. The result is to extract more nitrate from the caliche, and less is thrown away in the ripia; hence, by this latter system, an economy is effected in caliche, which more than balances the extra consumption of fuel.

In the closed cachucha the caliche is first placed in boxes made of perforated iron plating, which are mounted on wheels, and are pushed along a tramway into the cachucha. To overcome the difficulty of stirring up the mass, boxes have been made of a circular shape, and capable of revolving on their standards when locked to an axle when worked by a wheel on the outside. This plan, however, proved a failure, on account of the accumulation of insoluble matter at the bottom of the cachucha, which completely wedged in the boxes, and the attempt to give the latter a rotary motion could only have been done at the risk of breaking the couplings and damaging the boxes themselves. This plan might be carried out by making the plant stronger, and by allowing adequate space for the insoluble matter which escapes from the boxes; but then that would be objectionable, on account of the large steam space it would afford in the cachucha, and the consequent impoverishment of the solution through the condensation of the steam.

There are other forms, known as egg-shaped cachuchas, owing to their similarity in form to an egg placed on its smaller end. These offer great facilities in the operation of charging and discharging the material. The caliche is conducted over a road to their upper part, and shot down. After being boiled, the solution is tapped, and the refuse allowed to fall into trucks placed beneath, which convey it to the spoil bank. The chief disadvantage of these cachuchas consists in the necessity of having at command considerable height for the approach road, and consequently they are chiefly used at those places where an adjoining hill affords that height, the manufactory being built at its base. Where no hill is available, the trucks may be raised on an inclined plane.

Chemists interested in the trade have of late been engaged in searching for a method of extracting iodine from caliche, but as the operation is known but to a few, and when known kept a dead secret, the author does not propose to touch further upon this subject.

The labor required for the different operations attendant on the production of nitrate is chiefly supplied by Bolivians. Great numbers of these people annually cross the Cordilleras, taking with them their wives and children, and offer themselves for hire at the saltpetre establishments. They earn from one to two dollars per day, and perform their work well, and they are much esteemed by the manufacturer for their docile disposition and readiness to obey orders. Their migratory habits never allow them to remain long in one locality; they remain perhaps six or twelve months, then leave in a tribe, to go to some adjacent establishment. Chinese coolies are employed at some places, but their feeble strength, and lack of *physique*, render them incapable of performing the hard work of mining, and the rough duties attendant upon this manufacture.

Mechanics, bricklayers, carpenters, and skilled artisans of any description command high wages in this district; and the manufacturers can well afford to pay them highly, as they calculate upon at least 50 per cent. of the wages returning to their pockets, by the sale of provisions and commodities of every description, of which they are the sole purveyors (the truck system).

Below is a copy of the balance-sheet

of the working of an oficina, which may be taken to show a fair average of the profits made in prosperous times by careful management:

March, 1873.

DISBURSEMENTS.

	Soles.
Elaboration	7,680
Coal, 2,300 quintals, at 1.5 soles	3,450
Mules	800
Provisions	3,000
House and office	1,200
Repairs and loss	600
Gross profit	3,670
	20,400

ENTRIES.

	Soles.
Sale of 14,000 quintals of nitrate, at 1.10 soles per quintal	15,400
Item provisions	5,000
	20,400

In this case the nitrate was delivered at the manufactory, from whence it had to be conveyed to the port by the purchaser, either by rail or by mules.

The cost of conveyance by mule service is fixed according to the distance of the manufactory from the port. Thus from La Noria to Iquique the price is from 5 to 6 reals (Peruvian), and from other oficinas half the distance from the port the price is only half that amount. A good mule will carry three quintals, the usual load is two down to the port, and one-and-a-half up loaded with coal or provisions. Frequently the mules have to perform the journey there and back, some 28 miles each way, without touching water, owing to the total absence of that element in its natural state. For the use of the inhabitants sea water is condensed, but when the machines fail, and there is a scarcity, the price is too high to give drink to the mules; two cents per gallon is the price paid at Iquique for condensed water, and sometimes as much as four is paid.

The construction of the Iquique and La Noria Railway did much to take the transport away from the mules, but it did not entirely succeed in doing so, owing to its inability to convey the enormous quantity of saltpetre daily brought down. The line starts in a northerly direction from the port, making towards the coast-cliffs, which it reaches at a distance of three miles, and at an elevation of some 300 feet. From that point it reverses its direction to the north, and creeps up the hill side on an incline of three per cent. until it attains the summit of the coast-cliffs at the station called Mollo, which is situated at an elevation of 1,630 feet above the sea, and at a distance of ten miles from Iquique.

From thence it follows a general direct course on to La Noria, winding itself round hill sides in curves of from 300 to 500 feet radius, sometimes raising itself high above the surrounding country where the latter dips and assumes the shape of a bowl, over the extreme edge of which the railway must necessarily pass, and at other times penetrating through deep cuttings of irregular porphyritic rocks, clearly indicating the volcanic agency that must have occurred to have caused their displacement, until it reaches the district known as La Noria. Throughout, the railway is of the 4 8½ gauge. Where there were cuttings near, their *debris* supplied the fillings, and at other places trenches were dug at each side of the line. The chief want we experienced was soft earth or sand to pack in the permanent way with, which was very scarce, owing to the hard nature of the surface of the ground.

Though it is not proposed to give in this paper a detailed description of the railway, the points bearing on the transports of saltpetre are set down as follows:

The grades between Iquique and La Noria vary from 3 to 5 per cent, and the up trains generally consist of the following loads:

	Eng. Tons.
One Fairlie locomotive in running order	54
Four American double bogie cars loaded, say 24 tons each	96
One tank holding approximately 2,000 gallons of water and its car, say	22
One employé's car	12
	184

The inequality of the traffic, the up traffic not amounting to a third of the down, necessitates the hauling up of empty cars. Thus trains of from 8 to 10 empties are dispatched. The Fairlie engine has done some good service on this line, where it has shown its superiority over that of the American type. I will

compare the work done with the theoretical duty the Farlies should perform. The average speed up the line is about 10 miles per hour, and loads up to 200 tons, including the engine and water tank, are hauled up inclines of 1 in 22 and even as steep as 1 in 20. Having the diameter of cylinder 15 inches, the stroke 22, and the driving-wheel 42 inches in diameter, and a mean pressure in the cylinders of 100 lbs., the following formula expresses the theoretical tractive force of the engine in lbs :

$$\frac{15^2 \times 100 \times 22}{42} = 11{,}785 \text{ lbs. for a single}$$

pair of engines, which must be multiplied by 2 for the Fairlies, and which makes 23,570 lbs. total tractive force. The resistance due to gravity would be $\frac{2{,}240}{22} = 102$ lbs. per ton, and that due to friction say 10 lbs. The haulage force of the engine then is found thus :

$$\frac{23{,}570}{102+10} = 213 \text{ tons.}$$

On the downward journey, as many as 20 cars loaded with saltpetre have been lowered by these engines, but as the risk attendant upon the train breaking away is so considerable, the number has been reduced to 15 or 12, representing a total load of some 340 tons. Each car is loaded up to 264 quintals, or nearly 12 English tons, and the bags are laid at each end, immediately over the bogie frames, leaving the middle part of the car empty. The price charged by the late company was 1½ cents per quintal per mile, being the price allowed in the concession from the Government, thus taking the distance of the manufactory from the port, about 33 miles, the cost of conveyance would be five Peruvian reals (equivalent to 10 Spanish) per quintal. From an extract taken from Consul Hutchinson's report on this trade, published in the Foreign-office Blue Book of Consular Reports for 1873, we learn that in eleven months of the year 1872 the total export of nitrate from Iquique was 3,983,798 quintals, or 362,163 per month. Since then it has no doubt increased, but we will take only that amount which would correspond to over 12,000 quintals, conveyed daily to the port. For 120,000 quintals, some 45 cars would be required. Supposing the railway worked for a monopoly of both the up traffic (coal and provisions) and the down traffic, it could only approach such a monopoly with the following train service :

Locomotives running per day.		Cars.
3	trains of provision and fuel cars, 4 cars loaded and one empty.	15
4	trains of 8 empty cars each....	32
2	trains of water tanks to supply the above, 8 tanks each.	
9	Cars.....	47
	Water tanks.....	16

This is only taking the up traffic to be one-fourth of the down ; most probably it would reach as much as one-third, if not more, were the railway to secure a monopoly, then a greater number of trains would be required. The late company never possessed sufficient rolling-stock to attempt anything of this kind, and, in addition, they had, as the present company have, to contend with the water question, which, in the author's opinion, would, were it to remain as at present, entirely prevent their securing a monopoly of the traffic. For working the first section, to Molle, the water is obtained from sea-water cleansed at Iquique, and for working the remainder of the line it is brought from a well in the interior in tanks to Molle, at an enormous cost. Until a proposed scheme for obtaining water from the interior, to be conveyed to the railway stations at Iquique through piping, is carried out, the railway company must continue to work under the great disadvantage enumerated above.

To show the large traffic returns which this important railway might, under certain conditions, earn, it is only necessary to refer to the amount of saltpetre shipped from the port of Iquique, in 1872, which approached 4,000,000 of quintals. The entries would be then, assuming a monopoly :

	Soles.
4,000,000 of quintals, at 5 reals, taken to port.....	2,000,000
Up traffic, consisting of coal, corn, hay, provisions, and material of all descriptions, say one-third of above, 1,333,333, at 5 reals.....	666,666
Total of entries...	2,666,666

Or equivalent to a sum of over 583,333 pounds sterling.

The author refrains to touch upon the working expenses, for fear of acting in opposition to the directors' wishes.

There are at present some 3,000 to 4,000 mules competing with the railway.

This line, as well as that to Pisagua to Sal de Obispo, was constructed by a private firm of Peruvians, Messrs. Montero Brothers, who are the owners of the property, and by whom it was worked until within the last five months.

Whilst dealing with the conveyance of saltpetre to the port, I must not omit to mention an unsuccessful endeavor made by a company to convey down the nitrate in a liquid state through iron piping. The company which entertained this project was called "La Compania Salitera Barrenechea," now, I understand, in liquidation. The objects the promoters proposed to obtain were, firstly, to avoid as much as possible the use of steam in the reduction of the mineral, and thereby secure an economy in coal. Secondly, to save the freight of conveyance by rail or mule to the port. The first was sought (though I never visited the works at the mines), I believe by dissolving the caliche in vertical pans by passing cold water through it, resembling the process of filtration. The solution drawn from the bottom of the pan was pumped up to high ground (for the mines lay in a hollow), whence it ran down by gravitation through piping to the works at the port. At the latter place the solution was boiled in large circular pans, heated by a fire placed so as to spread over the entire bottom of the pan. The result of the first experiment may be easily anticipated. The solution, impregnated with the salts it held in suspension, soon began to precipitate them, and a thick cake of nitrate and salt shortly collected at the bottom of the boilers, which were in consequence burnt, and rendered useless. Notwithstanding the wrong principles upon which the plant was designed, which the directors recognized, and which could have been remedied by an additional expenditure, the company apparently took no steps to modify these evils, and the real cause of their suspending their operations last September was, I understand, the fear they entertained as regards the quality of their lands. With caliche containing a large percentage of common salt no profit is to be made by working it, either with this or another system, though, it must be understood, I do not give any opinion upon the nature of the mines in question.

As regards the extent of land supposed to contain saltpetre, no formal measurement or survey has been made, for frequently land is supposed to contain nitrate which, on being opened, proves to be barren in that mineral.

The lands round about La Noria were those first worked, and there remains very little "virgin land" left in that quarter. There are large spaces however, left untouched on the Pampa di Tamarugal, and nitrate is supposed to exist all along the southern border of the pampa, between the points known as Pozo di Almonte and Sal de Obispo, which are marked upon the map.

Numerous deposits are reported to exist in the south, where some oficinas have been opened, and a railway made to them from the port of Patillos, but for the reasons before stated, namely, for the want of a geological survey, it would be impossible to give any definite opinion as to the area of land containing saltpetre or its quality. Large portions of land in the south are said to contain nothing but beds of common salt.

I observe that Mr. Markham says, in his "Travels in Peru and India," "it is calculated that the nitrate grounds in this district (Tarapaca) cover 50 square leagues, and, allowing 100 pounds weight of nitrate for each square yard, this will give 63,000,000 tons, which at the present rate of consumption will last for 1,393 years." I cannot agree with Mr. Markham that the deposits cover so large an area as 450 square miles, but it might amount to 100, though that can only be a supposition, and no opinion can be made in reference to the quality of the nitrate. The estimate of one quintal to the square yard is too low in my opinion. I found, on having made an analysis of two specimens of caliche, they contained the following substances:

1st Specimen (White).

	Per cent.
Nitrate of soda	48
Common salt	40
Insoluble matters	12
	—100

2d Specimen (Yellow).

Nitrate of soda	55
Salt	35
Insoluble matters (containing sulphur)	10
	100

The mineral is found in layers of from a few inches to three yards in thickness, and I think three quintals per yard of surface is a fair average for land containing nitrate in sufficient quantities to repay its working. Provided these lands in the south proved to be good, we may in that case assume a total area of 100 square miles; but otherwise, excluding these, it would not be safe to count upon more than one-third of that area, 100 square miles at three quintals per square yard would give 42,240,000 tons, which at a consumption of 3,000,000 quintals per annum would last over three centuries. All these grounds have been claimed under the mining laws of the country by private individuals, and I believe the Government does not possess any of them at the present moment.

I will now describe the physical features of the country upon which are based my suppositions as to the origin of these deposits. Ascending from the sea-board the cuttings in the railway bring to view rocks of porphyritic formation. Granite is seen in a state of decomposition crossed with veins of quartz, and in other places are beds of coal and sandstone. At the summit the railway cuts through a bed of white limestone resembling marble by the polish it will take, and for which rock it has been mistaken by many. To this coast range succeeds the vast plain of Tamarugal with its alluvial coating, and which extends some thirty miles to the foot of the second range of mountains, chiefly composed of sandstone, and among which extinct volcanoes have been recognized. Another level plain intervenes between these latter and the range of mountains known as the Cordillera proper, among which is situated the famos volcano "Isluga."

Returning to the Pampa of Tamarugal, a group of hills, ranging from 200 to 500 feet above its level, borders its western extremity. On the slope of these hills lie the deposits of salpetre, and in no case has that mineral been found on the pampa itself On its eastern side stands the second range of mountains already mentioned. These mountains are pierced at frequent intervals by deep ravines, at the bottom of which small streams find their bed, but the uniform layers of boulders packed up on each side of the ravines leads the imagination to picture the large rivers, which at one time, no doubt, traveled down these channels on their way to water the wooded plains of the pampa. Upon entering the ravine of Tarapacá, two leagues of ground covered with boulders have to be traversed, and a deep gully still can be traced in the neighborhood which points out the course taken by a pre-historic river.

By one of those revolutions in nature, the occurrences of which are proved by the researches of the geologist, the rains ceased to fall with their accustomed abundance, and have left, where formerly were forests and grassy plains, nothing but an immense arid desert. But though the rains are now insufficient to form themselves into rivers, they fall with regularity, and, being absorbed by the earth, they percolate through porous strata, to empty themselves into the natural reservoir beneath the surface of the pampa. Thus water may be seen jetting out in springs at the foot of the eastern range of mountains, where it is obtained in large quantities by the natives, by driving tunnels into the yellow sandstone which forms the foundation of the slope. The crust at this point is chiefly sand and a limestone having a very washed appearance, from which water is also obtained, but it does not repay the working, as it is soon dried out.

At Pica there are two basins supplied with water in this manner, the one placed some fifteen feet above the other. The top one receives from its tunnel supplies of cold water, whilst the bottom receives warm water (90° Fah.). At a point a quarter of a mile up the hill, and (perhaps) at an increased elevation of 100 feet, another basin receives warm water; thus the anomaly is presented of a cold stream running between two hot streams.

Following the section of the pampa westwards for about ten miles, water is found beneath the surface at a depth of three yards. In this latitude a novel kind of cultivation is practised, namely,

the capillary attraction which some plants possess to an inordinate degree is utilized by making them suck up the water through several feet of earth. The upper crust of saliferous sand is cleared away to a depth of some three feet, until the alluvial soil is encountered. A trench is thus formed, measuring fifty feet wide and several hundred feet long, and the excavated material is packed up on its borders. Alfafa, vegetables, and different cereals thrive well in these pits, and the cultivation proved so successful that the Government, who in that country must have a finger in every pie, established an agency to collect rents and to plant a farm on their own account, with the object of supplying the soldiery with vegetables.

At my last visit the Government agent was erecting a windmill destined to raise the water by means of a pump, so as to attempt surface irrigation. Considering the force and constancy of the south-westerly winds, the attempt will most likely prove successful.

Resuming a westerly course at the termination of another eight miles, the water is encountered at a lower depth, namely, at about six or eight yards below the surface, but is still sweet to the taste. Another eight miles in the same direction and the western hills are arrived at, where the water is found only at depths of from 40 to 100 yards, and, with only a few notable exceptions, so strongly impregnated with saliferous matter, that it is unfit for the use of animals. Thus the pampa may be compared to a cup, slightly tilted up at one end and filled with a fluid, the surface of which is depressed from the natural level by the weight of a covering whose depth increases in proportion to its distance from the raised end. This subterranean reservoir is supplied directly from the rainy district, and as a proof of the free connection which exists between itself and its sources, it is only necessary to refer to the fact of the simultaneous rising of the water in the wells almost immediately after the commencement of the rainy season.

Now, taking into consideration the facts above enumerated, the position of the deposits beneath the surface of a lee-shore, the proximity of numerous volcanoes uniting with their lava, probably large quantities of salts, sodas, sulphurs, and other substances, and, lastly, the direct communication maintained by the rivers between the volcanoes and the nitrate grounds, would it not be reasonable to suppose that these deposits derive their origin from volcanic discharge? Is it not probable to suppose the lava discharged during eruptions, and falling into the ravines, was snatched up by the rivers in the latter, and whilst its heavier particles were deposited in the neighborhood, the lighter, consisting of the salts, were conveyed across the desert and thrown upon the opposing shore, which became coated with the deposits on the withdrawing of the waters in the dry season?

With the arrival of the fogs in the winter, this coating of soda would experience rapid liquefaction through the condensation of the fogs, and the product would be absorbed by the porous soil of the formation.

It would seem that no suitable place offered itself for the accumulation of the deposits on the eastern side of the pampa, where they would have been rapidly dissolved, and washed off by the rains, and, indeed, where the hardness of the formation would not have permitted of their percolation.

Bolleart, in his "Antiquities of Peru, &c.," whilst opposing Darwin's opinion, that the pampa was formerly an inland sea, and obtained its salt thereby, says: "As to iodic salts, we need not look for them to the sea, as iodine and bromine exist in the minerals of the regions;" and in another part he hints at the probability of their being derived from volcanic sources.

If Darwin was right, would not the greater part of the pampa be covered with salt on the evaporation of the sea-water? But it is not so, as no beds of salt on the pampa have been discovered after boring for a considerable depth. It lies only on the slopes of the western shore.

The heavy fogs to which I have alluded appear between the months of March and October, and on condensing leave a thin coating of chloride of sodium on projecting rocks and stones, or any impediment which seems to arrest their course.

To bring back to memory the origin of

these sea fogs, I will quote what Captain Maury says about those of Newfoundland, in his "Physical Geology of the Sea," article 166: "The fogs of Newfoundland, which so much endanger navigation in the spring and summer, doubtless owe their existence to the presence, in that cold sea, of immense volumes of warm water, brought by the Gulf Stream." A distinguished scientist, Señor Raimondi, in his "Apuntes sobre la Provincia litoral di Loreto," says at page 7: "The immense extent of sand stretching along the coast of Peru, in some places from 15 to 20 leagues in breadth, has likewise to do with the absence of rain, because, being a good conductor of caloric, the sand, acted upon by the sun, evaporates a current of warm air, which prevents the watery vapors already spoken of from being condensed. In winter time, the atmosphere being of course colder, and the sand, being a better conductor of heat than the water of the sea, becomes colder than the latter, so that its low temperature causes the condensation from which we have the fogs so general in winter time on the coast of Peru."

It appears to me, in addition to this last reason given by Raimondi, that the fogs are caused just in the same manner as those off Newfoundland, with the difference that, in lieu of warm water pouring itself upon cold, the cold water of Humboldt's current, coming from the south Polar regions, mingles with the comparatively warm waters of the Pacific coast, thus producing the same effect. These fogs appear at night time, when frequently the thermometer descends below freezing point, to rise again, at 10 A. M., to 60° Fah., and at noon to 80° Fah. in the shade.

To strengthen the supposition of these deposits having been created through volcanic agency, I will again quote Humboldt; at p. 397 in vol. iii. of his "Travels in South America," he says: "The enormous masses of muriate of soda recently thrown up by Vesuvius; the small veins of that salt which I have often seen traverse the most recently ejected lavas, and of which the origin (by sublimation) appears similar to that of ologist-iron deposited in the same vents; the layers of gem salt and saliferous clay of the trachyte soil of the plains of Peru, and around the volcanoes of the Andes of Quito, are well worthy the attention of geologists who would discuss the origin of formations."

I must mention that the grounds are nearly everywhere covered with flat pieces of clinkstone or phonolite, averaging in size from a few inches to a square foot. A strong opinion is entertained by the natives that these blocks of stone are aerolites. As they belong to the trachytic family, it is probable to suppose their having been washed down from the volcanic mountains, and to account for their being found on the top of hills of moderate height, an upheaval might have occurred subsequently to their being deposited.

If we admit Humboldt's view as regards the sometime disposal of materials discharged from volcanoes, the origin of the saltpetre deposits will have been almost proved to demonstration, for the volcanoes would supply the materials which would be conveyed by the hydraulic agency I have attempted to describe, to the site they now occupy, where, after being dissolved by the fogs —naturally converted into liquid—and absorbed by the earth, in union with nitrogen derived from the atmosphere, they are dug out as nitrate of soda, for the use and to promote the prosperity of man.

The author has abstained in this paper from touching upon the use which is made of nitrate in this and in other countries, for he considers the important position it occupies in various compounds, and its large employment in agriculture, well deserve a special study and the preparation of a second treatise.

THE *Independance Belge* gives some curious statistics relative to the consumption of wood in France. A large quantity of soft wood is used for making toys, and to give an idea of the magnitude of this trade it will be sufficient to take one article alone, children's drums, of which in Paris alone 200,000 are sold every month. The total number made annually in France is estimated at 30,000,000, while a considerable quantity of wood must be consumed to supply 60,000,000 of drumsticks.

EXPERIMENTAL RESEARCHES IN BESSEMER WORK.

By W. MATTIEU WILLIAMS, F.R.A.S., F.C.S.

From "Iron."

In the last number of the *Journal of the Chemical Society* is the following abstract of the observations of F. v. Ehrenwerth:—"In Bessemer steel, obtained by blowing pig-iron rich in silicon, it is remarkable that the greater the amount of silicon present, the harder in general is the steel. It is only in the softest qualities that the silicon disappears, and with it the manganese, for the most part, or entirely. In the selection of these qualities the Eggertz method may therefore be used. But in the case of the hard varieties containing much silicon (after exerting greater influence than the carbon), this method can lead only to errors and inaccuracies in the selection. The manganese and silicon in such a case should eitheir be supposed constant, or be estimated, and a combined scale being set up, the position thereon could be determined. The Eggertz method loses therefore nothing of its value for carbon estimations, or in the selection of varieties of steel in which silicon is not present."

Having made or superintended about fifteen thousand carbon determinations (chiefly in Bessemer steel) by Eggertz's method, and carefully observed the connection between the quantity of carbon thus indicated, and the practical properties of the steel containing it, I venture to state some of the results of this experience, which have satisfied me that many of the objections made to Eggertz method are merely frivolous, and others are entirely baseless.

The above quoted conclusions of von Ehrenwerth belong to neither of these categories, but, on the contrary, appear to be the results of careful practical observation and research.

The reader is probably aware that this method is based on the fact that when steel or cast iron is dissolved in diluted nitric acid (sp. gr. 1.2 is the strength actually used) the solution has a brownish color varying in depth with the quantity of combined carbon in the steel or cast iron; and that it is carried out by first making a standard solution of cast steel of known composition and comparing to this the color of a similarly made solution of the steel to be examined.

Some have condemned this method because it is less accurate than those which the objectors prefer to use, others that it cannot be applied at all to the determination of very small quantities of carbon, and some chemists have even maintained that it is altogether unreliable and worthless.

Taking the last objection first, it is doubtless true that in unskillful hands it may fail to such an extent as to be practically worthless. A man may be a learned chemist and even a good gravimetric analyst, and yet fail when he first attempts a volumetric and colorimetric determination of this kind. A certain amount of special technical skill, only obtainable by special practice, is necessary, in order to carry out this method expeditiously and satisfactory. Besides this, there is the possibility of partial color-blindness disturbing such determinations. The late Dr. George Wilson found, by repeated experiments, that, on an average, about one in every thirty of the pupils attending his class for chemistry was decidedly blind to certain colors, and that scarcely any of them were aware of the fact until his experiments had demonstrated it. This is necessarily a source of considerable possible misapprehension of all colorimetric determinations; the "personal equation" is vastly more disturbing here than in the weighing of precipitates and potash bulbs. As the carbon determination is more dependent on light and shade than on tint, color-blindness may not interfere so seriously as in some other cases.

Great care is necessary in order that the conditions of solution shall be the same, both for the standard steel and that to be examined. The acid should be the same, and free from chlorine, the temperature the same, both during solution and at the moment of comparison. This is best attained by making both

solutions together in similar tubes immersed in the same water bath. Normal solutions of burnt sugar that have been recommended are not at all reliable; they become lighter by keeping, apparently by the aggregation and deposition of the minute carbonaceous particles upon which their color depends. The solution of the standard steel itself is liable to similar change, and must, therefore, be continually renewed. I have no hesitation in affirming that where this method has altogether failed, when applied to samples containing more than ¼ per cent. of carbon, the failure was due to the operator and not to the method.

As regards the first objection, it is admitted at once, that the limits of error are wider in this than in other possible methods of carbon determination, for besides the personal equation above described its accuracy is obviously limited by the previous analysis that determined the carbon of the standard, and thus its own special errors may be either added to or subtracted from this, according to their direction.

But the practical merits of this, as of all things else, must be measured by fitness for intended purpose. By Eggertz method, skillfully conducted, the carbon combined with iron may be determined within five-hundredths or 1-20th per cent., which is sufficiently approximate for commercial purposes, and a demand for greater accuracy is mere pedantry.

The more accurate methods of carbon determination are so tedious that they are simply worthless for the purposes to which Eggertz is applied. To prove this I have only to state the fact that as many as forty blows of Bessemer steel were sometimes made at the Atlas Works in one day, and the carbon determinations of each of these were required within a few hours, or they would be useless. By Eggertz method my assistant was able to make all the forty determinations within five hours of obtaining the test-ingot drillings, and get his dinner in the meantime.

The second objection is quite sound. For quantities of less than two-tenths per cent. of carbon the Eggertz method is very uncertain. By using double quantity of steel and reading the result as half, it is sometimes possible to determine as low as one-tenth per cent. ; in other cases this cannot be done, on account of a green tint, which occasionally appears in solutions of such slightly carburetted iron. Why this green tint should appear in some solutions and not in others I am unable to tell. All my hypotheses respecting manganese, &c., broke down when searchingly investigated, and therefore I leave the riddle for some one else to solve. When this green tint is absent, which is usually the case, we may, with care, get down to about 0.1 or 0.15 per cent. with tolerable reliability. In these more delicate and difficult determinations of shade it is well to use more than one pair of eyes, if possible, each observer independently noting his result and then comparing.

Another class of objections bear mainly upon the question of whether the knowledge obtainable by these carbon determinations is of any practical use in checking the proportions of spiegeleisen that should be used, and in classifying the ingots in order that the steel made by each blow should be devoted to its proper purpose. I pass over without further notice the incurable conservative stupidities of a certain class of workmen, foremen and managers, who blindly denounce every application of science as "theory," and who would extinguish every man who attempts an improvement by covering him with their bugbear epithet of "theorist ;" but shall respectfully consider the fair objections of those intelligent practical men who have endeavored to use the information supplied by the chemist, but have met with difficulties and contradictions in so doing.

The source of one of these difficulties is pointed out in the above quotation. Silicon does undoubtedly add to the hardness of steel, and still more so to its brittleness. It is, therefore, possible to have two samples of Bessemer steel, one containing 0.4 per cent. of carbon and the other 0.5 per cent., and yet the first may be quite as hard or a little harder than the second, and much more brittle. This would be the case if the first contained a notable quantity of silicon, and the second only the ordinary trace. Exclusive reliance on the carbon would, therefore, in such a case be misleading. According to the carbon determinations the first should be used for rails and the

second for tires—according to actual hardness their uses should be reversed, as tires should be a little harder than the rails upon which they run.

I have only supposed a small discrepancy here because, practically, silicon can have but a small effect, seeing that the Bessemer process is especially effectual in oxydizing and removing silicon, which can only remain behind in practically appreciable quantity when the blow has been stopped too soon, or the spiegeleisen of bad quality.

There is, however, another and far more frequent and serious cause of discrepancy, which I discovered while at the Atlas Works. As a clear theoretical and practical understanding of this affords important aid to the successful working of the Bessemer process, I will state pretty fully the facts which led me to it.

The late Mr. George Brown was the manager of the Bessemer department, and to him a report of the carbon determinations of every blow was delivered daily. He had been engaged in steel making from boyhood, and was well versed in all the practical details of his business; besides this, he had, without pretending to be a chemist, a sound acquaintance with what is known of the chemistry of steel, and broad philosophical convictions of the value of chemistry and its applications to steel-making, and these convictions were based on practical experience, which prevented him from falling into the errors of the over-learned, who would regulate everything by mere laboratory results. He accordingly applied the carbon determinations with their due and proper checks and limitations. Two test ingots were made from every blow—one for the laboratory drillings, the other for a *mechanical* test of hardness and brittleness by bending. These were marked with corresponding numbers and the chemical and mechanical results (which were obtained quite independently and apart) were compared. Usually they agreed in a remarkable and satisfactory manner, but whenever this was not the case I was informed of the discrepancy, and repeated the analysis, using this time drillings from the mechanical test-ingot to check possible error in numbering. When the discrepancy was confirmed, we "put our heads together" and tried to puzzle out the cause. In some cases underblowing and consequent presence of silicon afforded sufficient explanation; at other times we traced it to silicon in the spiegeleisen. The influence of silicon, as described by von Ehrenwerth, was well understood by Mr. G. Brown. In other cases the silicon explanation would not fit the facts; it threw no light upon the discrepancy and we were left in the dark respecting it.

I had already made several observations and experiments which led me to the conclusions—rather heretical at that time—that sulphur was far less mischievous to steel than phosphorus, and that the generally-received belief in the superior malignity of sulphur was only sound when applied to ordinary malleable iron. These conclusions are stated in a communication to the *Chemical News*, February 19th, 1869, in controversion of Dr. Miller, who stated that 0.298 per cent. of phosphorus in steel-iron "is obviously not such as to injure the quality," of Dr. Paul's assertion that 0.24 per cent. is quite a harmless quantity, and the general opinion then prevailing and expressed at a discussion in the Chemical Society to the effect that small quantities of phosphorus were harmless, or even, as some Continental chemists had stated, were beneficial to steel. Having satisfied myself that phosphorus is the worst enemy to steel, I made special analysis of the pigs and spiegeleisens used in the Bessemer department, and by following up this investigation, ultimately discovered that in every case where the phosphorus was above average the steel was harder than it should be according to its percentage of carbon, and that whenever the phosphorus was below average the steel was softer. I found that the hardening power of phosphorus was about three times as great as that of carbon, that one-tenth per cent. of phosphorus conferred about the same degree of hardness as three-tenths per cent of carbon. Not only was the hardness increased by the phosphorus, but the tenacity also. The breaking strain of the phosphorized steel as shown by tearing it asunder by the gradually-applied pull of an hydraulic testing apparatus, was remarkably high, much higher than steel containing

a similar amount of carbon and little or no phosphorus. These experiments showed that one, two or three-tenths per cent. of phosphorus increased the tenacity of iron as thus indicated—to a much greater extent than a corresponding amount of carbon, but they were not sufficiently extended to enable me to state in reliable figures how much greater.

Some readers, even at this date, will probably be puzzled by the foregoing statement, and suppose that I have contradicted myself; will say that if phosphorus thus gives hardness and tenacity, even to a greater extent than carbon it must be beneficial, and that it may be used instead of carbon. This was exactly the reasoning that led to the errors I endeavored to refute in the letter to the *Chemical News* above mentioned. The conclusions of Dr. Miller, Dr. Paul, and many others, were based on the tenacity displayed by the ordinary method of testing, by a gradually increasing steady pull, the breaking strain of iron, steel and other substances. If steel only required such hardness and such tenacity, then phosphorus *would* improve it. Further examination, however, shows that this phosphorus hardness is treacherous, it is accompanied with most deleterious brittleness. Glass is very hard, and will resist a tremendous longitudinal strain gradually applied, but is shattered by a blow or any other sudden vibratory shock. This is just the quality which I found to accompany the hardness conferred on iron by phosphorus. It produces a glassy rather than a steely iron, and, in small quantities, is less damaging to soft iron than to hard steel, especially if the soft iron contains sulphur; as phosphorus and carbon both tend to neutralize hot-shortness. Karsten goes so far as to state that up to 0.5 per cent. phosphorus is not damaging to iron, but rather improving. This, however, is an exaggeration.

The trials upon which I based the conclusion that phosphorus is especially deleterious to steel were those made by the drop test, and by hammering, or sudden bending. Steel containing phosphorus is more liable to crack, break, or crush when thus tested, and if a tool with an *acute edge*, such as a knife, a carpenter's chisel, &c., is made of such steel, its edge breaks and becomes notched if, in tempering, it is left hard enough even for cutting wood.

The most decisive experiments, however, were not quite so direct and simple as these, and were suggested by the fact that there is a practical limit to the amount of carbon that can be added to Bessemer steel. If this limit is slightly exceeded the steel, when hammered or rolled, cracks at the edges; if it is largely exceeded, an ingot placed as usual under the steam hammer crumbles like sandstone, even at a welding heat. In some samples this occurs at 0.75 per cent.; others will bear 0.90, 1.00, 1.25 per cent., or even more, of carbon without crushing. Why should this be the case with Bessemer steel and not with shear or pot-steel? was, of course, a very natural question. As the chief chemical difference between Bessemer steel and the best pot-steel is that in the former the sulphur and phosphorus of the pig remains unremoved, while in the latter these are taken out in puddling, or do not exist in the charcoal iron, I naturally replied that it must be one of these, and accordingly made analyses for sulphur and phosphorus in all the Bessemer pigs and speigeleisens that were used during a long period, and watched the results whenever a hard or highly-carburetted blow was made. It soon became evident that the phosphorus was the main cause of this rottenness, for the crushing point of the hard ingots and the cracking points of the ordinary daily bending tests rose with the fall of the phosphorus and fell with its rise, *i. e.*, the greater the amount of phosphorus the less carbon the steel would bear. This was a really important discovery, so much so that Mr. G. Brown requested me to keep it as a trade secret, which I have done during his lifetime, but am now under no further obligation to do so.

A statement of all the details of these experiments would be rather tedious, but a general summary may be interesting.

The average crushing point of the Bessemer steel produced in the ordinary course of working was at about 0.90 per cent. carbon. The average composition of the Bessemer pigs and spiegeleisens used from July, 1868, to May, 1869, was as follows:

	Pigs.	Spiegel.
Combined carbon.....	0.469	3.886
Graphitic carbon.....	2.719	0.474
Silicon.....	2.820	0.772
Phosphorus.....	0.082	0.056
Sulphur.....	0.139	0.148
Manganese	0.879	6.761
Iron (by difference)....	92.892	87.903
	100.000	100.000

The range of phosphorus in the pigs during this period (with the exception of one delivery, of which I shall speak presently), was from 0.02 to 0.15, and in the spiegeleisen from 0.03 to 0.12. As the pig-iron constitutes nine-tenths of the charge and is the most variable, this, of course, was chiefly watched. The quality of steel varied during this time and with these materials. There were two classes of variation—one that happened in a particular blow of inferior quality as an individual variation among a series: this class was generally referable to silicon and bad work, as above described; the other class of variations occurred in series, *i. e.*, the steel generally during a certain period was better or worse than average, and this period corresponded with the use of a delivery of pig of certain brand and quality. It was with these that I was now concerned, and I compared these variations of quality respectively with the variations of silicon, sulphur, manganese and phosphorus, and found that they fitted neither of the first three, but came as nearly in accord with the variations of phosphorus as the limits of error due to commercial analysis, mechanical testing, and possible variations of individual casts from the same blast-furnace, demanded.

The following five cases, showing composition of different deliveries and brands of pigs, will illustrate this:

	A	B	C	D	E
Combined carbon.....	0.62	0.20	0.50	0.37	1.25
Graphitic carbon.....	4.00	2.80	3.00	1.96	1.65
Silicon.....	1.40	2.33	2.00	4 08	2.15
Phosphorus.....	0.02	0.02	0.03	0.15	0.24
Sulphur.....	0 06	0.10	0.10	0.23	0.21
Manganese.....	0.38	1.92	trace.	1.15	1.10
Iron by difference.....	93.54	92 63	94.37	92.06	93.40

The deliveries of pigs, A, B and C, produced the best steel ever made during the whole time I was at the Atlas Works, and the order of the quality, as estimated by George Brown, was as I have stated them. With "A," a remarkably fine sample of "Cleator" pig, very porous and abounding with "kish" (*i. e.*, spangles of uncombined graphite), and a selected spiegel, George Brown produced first class tool-steel, equal to pot-steel, by charging it with 1.25 to 1.50 per cent. of carbon, which it bore without loss of weldability (pardon the word, on plea of its convenience). The steel from B was not quite as good and from C slightly inferior to B, but both far above average.

D produced the worst steel that was allowed to pass, and the steel from E was so bad that it was condemned, and all the pigs returned to their vendor. This sample of steel was rotten, with only 0.50 per cent. of carbon.

The degree of superiority of A to B, with equal proportions of phosphorus, is explained by the abundance of carbon in the former. This is an important element in the excellence of Bessemer pigs. The lower proportion of sulphur is also advantageous, though not of the predominant importance that was formerly supposed. This is indicated in E, where the sulphur, although excessive, is less than in D. The usual statement that the Bessemer process does not remove any sulphur and phosphorus is not strictly correct. When the carbon is abundant, and the blow is consequently vigorous and prolonged, a small reduction of both of these (more of sulphur than of phosphorus) does occur.

George Brown assured me that, with good management, he could work with

silicon as a substitute for carbon, and that an abundance of silicon is advantageous both for increasing the energy of combustion and the amount of cinder, but that to work with such iron the highest degree of skill is demanded, the blow must be carried on to the last moment, and the converter turned over only just before its contents begin to solidfy. This is attended with some risk. I have had no opportunity of verifying this, myself, but have firm reliance in the accuracy and candor of Mr. Brown.

The practical applications of the above chemical generalisations may be made to contribute materially to the success of Bessemer work. I will first state their bearings upon the most common applications of Bessemer steel—rails and tires. Correct adjustment and uniformity of hardness is a primary desideratum; the rails should be as nearly as possible alike, and the tires a little harder than the rails. It is obvious, from what I have stated, that the most skillful and scrupulous regulation of the carbon element will fail to afford the required uniformity unless the proportion of phosphorus in the raw material remains the same.

According to my estimate of the relative hardening powers of phosphorus and carbon viz., 3 to 1, steel made from pig D, containing 0.39 per cent. of carbon, will have about the same hardness as steel from pig A, containing 0.78 (the phosphorus of the spiegel is here neglected for simplicity of illustration), and therefore determinations of the phosphorus in pigs and spiegels are as necessary as determinations of the carbon in the steel. The importance of such determination becomes still more manifest when the other differences, besides mere hardness, are considered. Although, in the case just supposed, the D steel, with 0.39 per cent. carbon and 0.15 of phosphorus, may have the same hardness as the A steel, with 0.78 carbon and 0.02 phosphorus, it will by no means be of similar quality. It will be much more brittle, liable to fracture by vibratory strain, and less susceptible of that graduation of hardness obtainable by the tempering of true carbon steel.

Following up this difference, we arrive at a means of extending the Bessemer process to many other purposes than those to which it is commonly applied. All that is required for the manufacture of the best tool steel by the Bessemer process is to obtain pig-iron equal to A or B, and spiegeleisen of corresponding quality. It is not impossible to obtain this, but their is some difficulty in so doing, a difficulty which 20s. per ton added to ordinary prices of Bessemer pig would doubtless overcome. This tool-steel, of course, would demand the high percentage of carbon common to pot steel, which could easily be added, and with more certainty and uniformity than by the melting up of blistered steel.

But this is not all. There is a vast field open for the application of mild or semi-steel of reliable toughness and homogeneity. Bessemer steel-iron practically free from phosphorus and containing the lowest obtainable quantity of carbon, from 0.20 to 0.25 per cent., is invaluable for boiler-plates. Its tenacity is nearly double that of iron, and therefore it need be made of but little more than half the thickness of iron plates. These Bessemer plates being rolled directly from cast ingots are free from lamination, blisters and other irregularities of piled plates, and, by virtue of their carbon, can better resist the action of the fire. Girders and other elements of structure might be safely made of this semi-steel. We hear of many projects to build steel bridges. With this material the advantages of greater tenacity than iron, without the danger of brittleness, would be attainable.

Another application of such material may be mentioned. I had some sheets rolled from ingots containing 0.25 per cent. carbon and made from the same brand as A. These were sent to Messrs. Griffiths and Bowett, of Birmingham, who stamped them into vases and cylindrical cups of the form and proportions shown below. They were beaten and spun from a flat circular blank of the sheet metal. The object of the experiment was to ascertain whether a homogeneous cast metal could be used for the manufacture of tin-plate wares of superior quality. These are stamped first and tinned afterwards. When ordinary sheet iron, although made from the best charcoal-iron, is used, it often happens that

a portion of the surface is formed of cinder,—silicate of iron—that has not been completely squeezed out from the spongy mass of the puddled ball. This resists the tinning, and it has to be filed away, or the work, after much time and labor has been expended in shaping it, is quite spoiled and rejected as a "waster." The surface of the cast Bessemer semi-steel is perfect, and takes the tinning beautifully.

A multitude of other uses, such as steel pens, &c., might be named; but these are sufficient to show that there is still an unoccupied field for manufacturing enterprise in the establishment of a Bessemer work where only the fine quality steel and steel-iron, such as was produced from pigs A, B and C, should be made, and sold at prices corresponding to their quality. In such a manufactory no low-priced heavy work should be attempted; and if by mistake a few blows of ordinary Bessemer steel should be produced, the ingots should be sold to ordinary rail-makers, so that all the finished material bearing the brand of the works should be of uniform high-class quality. A reputation would thus be acquired, and large profits obtainable; but in order to secure such reliable quality the whole manufacture must be based on scientific principles, and no stint perpetrated in reference to the analytical examination of all the materials used, and the strict chemical investigation of every failure in respect to the quality of metal produced. Small or moderate-sized works, for high quality and high prices, rather than for large quantities, should be the aim. It might be advantageously affiliated with larger works, because there would, with every precaution, always be a liability to make inferior blows—by these I mean Bessemer steel which, though better than is now usually made, and useful for rails, &c., would not be good enough for the guaranteed quality that alone should bear the stamp of these works. There would thus be no absolute loss, even on the failures, and the high prices of the successful product would fairly reward the commercial enterprise and scientific skill demanded.

REPORT OF THE MASSACHUSETTS RAILROAD COMMISSIONERS.*

Abstracts from last Annual Report to Massachusetts Legislature.

The Railroad Commissioners respectfully submit their Seventh Annual Report.

The general and continued business depression incident to the financial crisis of September, 1873, has made itself felt much more perceptibly on the Massachusetts railroad system during the last, or second, year following the crisis, than it did during the first.

RAILROAD CONSTRUCTION

About fifty miles of railroad have been annually constructed in Massachusetts since the year 1835. In 1873-4, there were no less than 130 constructed; in 1874-5, the amount decreased to 41 miles, and during the past year has still further decreased to 33.75 miles. Of this amount, 24.95 miles were of the standard, or 4 feet 8½ inches gauge, and the remaining 8.8 miles of the narrow, or 3 feet gauge. There are now 23 miles of road of the last description in the Commonwealth.

THE MILEAGE OF RAILROADS.

The total length of railroads reported to the Board for the last year was 2,459.202 miles of main line and branches, with 693.266 miles of siding, and 626.034 miles of double track,—the equivalent in all of 3,788,502 miles of single track. An increase of 77.409 miles over the preceding year, 36.668 of which are additional sidings. Of these totals there are within the limits of Massachusetts 1,816.748 miles of main track and branches, 504.907 miles of siding, and 440.114 of double track,—the equivalent

* Brief abstracts from "Public Document," No. 29.

of 2,761.769 miles of single track. This affords one mile of main track or branch road to 4.29 miles of territory, and to each 909 inhabitants. These are the largest averages to be found in America, though small in comparison with those reported in some European countries, where the population averages as high as 8,000 to each mile of railroad.

COST OF ROADS.

The average cost of the roads of the standard gauge is returned at $57,307.64 per mile, exclusive of equipment, which has amounted to an additional sum per mile of $7,774.47. The narrow-gauge roads are returned at $16,640.07 per mile, and $3,592.32 for equipment. The average cost of an equipped road, irrespective of gauge, is returned at $64,657.06 per mile, but varies from $98,606.19 for the Boston & Albany to $9,316.20 for the Martha's Vineyard.

EARNINGS.

The average sum earned on each mile of main line and branch road operated, was $13,250.84 ; if, however, the double tracks are computed as additional single track, the average amount earned per mile was $10,737.65. The amount varied from $30,003.41 per mile on the New York, New Haven & Hartford road, and $25,039.90 on the Boston & Albany, to $2,008.03 on the Springfield, Athol & North-Eastern.

COST OF OPERATION.

The cost of operation has amounted to $9,329.38 on each mile of road in use ; varying from $17,135.12 on the Boston & Albany to $1,400.48 on the Springfield, Athol & North Eastern. It has consumed 70 per cent. of the gross earnings, leaving a margin of 30 per cent. as profit on the year's business.

FREE PASSES.

The subject of free passes over railroads has recently attracted much public attention. With a view to ascertaining the extent to which the practice of granting these passes had been carried, a series of interrogatories were addressed to the several corporations.

The practice as regards passes varies greatly. Each corporation lays down a rule for itself, which seems in some cases to be quite stringent, and in others extremely lax. Many of the corporations seem to have practically kept no record at all, especially of trip passes, and to be unable to give any definite information on the subject. It may fairly be regarded as matter for surprise that at this late day a matter of so much importance as the free use of their roads should have apparently excited so little attention on the part of such a number of railroad officials.

The whole system should be broken up, though this probably cannot be done by law. The true rule would be for the conductor of a train to take up a ticket from every person on it, except the train hands. He should not be allowed to receive fares on the cars without in return giving a ticket, which he subsequently should take up as a train ticket. Employés, from the highest to the lowest, should, when on the business of the company, surrender employés' tickets, countersigned by themselves. When public officials travel on public duty, they should buy their tickets, like other passengers, and their traveling expenses should be regularly refunded to them. In this way, and in this way only, could a true and accurate record of travel be kept, and the abuses always incident to the pass system cut off.

COST OF RUNNING TRAINS.

The average cost of running a train one mile has been $1.169 on the passenger service, and $1.235 on the freight service ; varying from $0.432 for passenger service on the Springfield, Athol & North Eastern, to $1.908 for freight service on the New Haven & Northampton. The average rate on all trains has been $1.195 per mile, or 1.3 cents more than last year.

PROPORTION OF PAYING WEIGHT TO DEAD WEIGHT.

The average number of passengers to each train during the last year was 66, and the average number of tons of freight was 64. The passenger trains, including locomotives and baggage-cars, averaged 122½ tons of dead weight, and the freight trains 212½ tons. Consequently, the returns would seem to indicate that the railroad corporations of the State haul 1.778 tons of rolling-stock for each passenger they carry, and 3.292 tons for each ton of freight.

TRAIN MILEAGE.

The total mileage of passenger trains run during the year was 9,589,921, or a decrease of 297,080 miles from the previous year, being a decrease of 3 per cent. in service, corresponding to a decrease of 2 per cent. in earnings. As regards freight, 8,710,611 trains were run one mile, a decrease of 973,991 miles from two years previous, representing a corresponding decrease of $2,702,059, or 16 per cent., in the earnings from that source.

FARES AND FREIGHTS.

The average fare charged per mile on all the roads was 2.42 cents per mile, ranging from 5.6 mills per mile for season-ticket passengers for long distances, to ten cents per mile for single-ticket passengers for very short distances.

STEEL RAILS.

As regards the track, it appears that 1,040 miles out of 3,085, or 34 per cent., this year, as compared with 29 per cent. last, of the entire main lines of the corporations, are laid in steel,—an increase of 156 miles over the amount reported last year.

TRAIN BRAKES.

One of the most gratifying features in the returns this year, as last, is the rapid application of the train-brake to the passenger-rolling-stock. At the close of last year, it had been applied to 313 locomotives, and to 997 passenger-cars out of a total of 1,294. It is now applied to 353 locomotives, and to 1,227 passenger-cars out of 1,361. When it is remembered that at the time of the accident at Revere, just four years ago, the train-brake had been adopted by a single one only of the Massachusetts corporations, the advance made in this important respect will be appreciated.

It is, however, to be regretted that neither the Providence & Worcester nor the New London Northern roads have yet adopted this great safeguard. It is also an unfortunate fact that a difference in judgment as to the relative merits of different inventions has caused certain other corporations, operating roads forming parts of through lines, to adopt different kinds of brakes. Accordingly, when the through trains are made up at connecting points, the cars and the locomotive are so equipped that the brakes do not operate. The trains, accordingly, are reduced to a reliance on the old-fashioned hand-brake. There is reason to believe that at least one serious accident, which recently occurred beyond the limits of the State, was attributable to this cause.

STATIONS.

The number of stations returned is 1,151,—an increase of 75 over the number previously reported,—being a station to every 2.14 miles of road operated. In Massachusetts, the proportion is somewhat different, being one station to every 2.27 miles of road.

GRADE CROSSINGS.

The number of grade crossings is still rapidly increasing. There are 2,774 of these returned for the present year, as compared with 2,660 for the previous one,—an increase of 114 in a single year; 607 of these are protected by gates or flagmen. The number of casualties at these points is yearly becoming more noticeable. This fact has repeatedly been referred to in the reports of this Board. During the past year, as will be seen by reference to that portion of the present report relating to accidents, new and striking illustrations have been afforded of the dangers necessarily incident to the crossing of railroads by highways at grade.

SUMMARY.

In conclusion, it may be briefly stated that the average mile of single track road (the mile of double track being estimated at two miles of single track) of which returns are made to this Board, has cost $44,500, and that its equipment has cost an additional sum of $6,000, making a total of $50,500 for the mile of single track equipped road, which is represented by $36,500 of capital stock and $16,900 of debt. The gross yearly revenue from it is $10,563; of which $7,436, or 70 per cent., is consumed in the cost of operation, and $3,127, or 30 per cent., remains as profit. Fifty-one per cent. of the revenue is derived from the passenger business, and 44 per cent. from freights, and the balance from miscellaneous sources.

The record of accidents shows that, notwithstanding the strict economy which

all the railroad corporations have been obliged to practise in consequence of the generally depressed condition of their business, the personal safety of their passengers has not been neglected, and compares favorably with the statement for any preceding year. No passenger has been killed upon a Massachusetts railroad, and but six have been in any way injured, from causes over which they had no control, or to which they did not directly contribute by their own carelessness.

The whole number of passengers carried by rail during the year is reported as 42,035,846, and the average length of journey made was 15.07 miles. It follows, therefore, that the average journey by rail resulting in injury during the last year has been 105,580,036 miles, or that in traveling upon the railroads of this State the chances are that a person will travel more than one hundred and five million miles before sustaining any injury whatever from causes beyond his or her own control. Or, again, a person traveling 200 miles per day for 312 days in each year, may travel for 1,692 years before sustaining any injury to which he or she did not in any way contribute by their own carelessness.

The ordinary average of accidents of this nature in Massachusetts for the past five years has been in the immediate neighborhood of one passenger to each 1,400,000 carried. During the past railroad year it has been only one to each 7,000,000 carried. How creditable this record is to the care and skill with which the various roads have been operated, may be inferred by comparing the record with that of other countries where similar records are kept and reports published. During a period of ten years—between 1859-69—one passenger was killed or injured upon the railroads of France to each 674,000 persons carried; and in England the average for the last five years has been one passenger killed for every 8,388,980 carried, and one injured for every 318,000 carried, exclusive of season-ticket passengers.

The following statement shows the proportion of passengers killed and injured to passenger journeys for the four years ending 1873, and the year 1874, respectively, in Great Britain:

	No. of passengers killed from all causes beyond their own control.	No. of passengers injured from all causes beyond their own control.	No. of passenger journeys, exclusive of journeys by season-ticket holders.	Proportion killed from causes beyond their own control to number carried.	Proportion injured from causes beyond their own control to number carried.
1870					
1871					
1872	143	4,698	1,589,912,975	1 in 11,196,570	1 in 338,423
1873					
1874	86	1,613	480,000,000	1 in 5,581,400	1 in 297,582

The total number of casualties incident to the operation of the railroads of the State during the year, has been 242, as compared with 279 for the previous year. Of these, 36 were to passengers and 84 to employés, and the balance of 122 were to trespassers on tracks and to persons at crossings, etc. One hundred and nineteen resulted in death to persons, and 123 in personal injury only. More than 42 per cent. of the casualties (103) were occasioned by the unlawful practice of walking upon the railroad tracks.

Eighteen cases of injury, of which 13 were fatal, have occurred at highway crossings at grade (only half the number for the previous year), and five of these fatal cases occurred by a single accident on the Old Colony Railroad at Fall River, on the 27th of June. Eight of them occurred at crossings protected

by gates or flagmen, and 10 where there were neither gates or flagmen.

The Commissioners wish again, as they have repeatedly done before, to call attention to the very rapid increase in the number of highway and railroad grade crossings. On September 30, 1872, there were reported of these, in this State, 2,228; and on Sept. 30, 1875, there were 2,774: an increase of 546 in three years, or at the rate of a new grade crossing every two days. The facility with which these seem to be granted by the several boards of county commissioners on almost every application is most unfortunate. There is now a highway grade crossing to every mile and one-eighth of railroad in the Commonwealth. During the three years—1872–74—there were 31 persons killed and 38 persons injured at these crossings. During the last year the two worst accidents which occurred at them were at crossings provided, in one case with a gate, and in the other, with a flagman, showing that these are insufficient protections. As population increases so does the danger, and the only real remedy is never to permit the crossing of a railroad by a highway at grade when it can possibly be avoided. The law authorizing these nuisances should be revised, with a view to their future restriction.

RAILROAD ACCOUNTS AND RETURNS.

For several years past the Commissioners have in each of their annual reports, freely criticised the methods of book-keeping in use by the various railroad corporations of the State, and the character of the returns made from them. The railroad returns are, and must continue to be, essentially unreliable, if not even deceptive, until a radical reform in the methods of railroad book-keeping is effected. Upon this point the Commissioners have no new considerations of a general nature to offer. The cause of the difficulty is obvious. It dates from the very origin of the railroad system, when it was not at all appreciated what that system as a whole, or the several members of it individually, were destined to become. Railroads were then regarded as purely private enterprises managed by corporate bodies, in the doings and business affairs of which the holders of the company's stock alone were interested. They were supposed to be more analogous to turnpike corporations than to anything else, and enjoyed much the same exemption from public supervision, nominal returns only being made by them. Gradually, however, the public character of the functions they exercised became better understood, until, as long ago as the year 1846, only eleven years after the first three roads were opened in Massachusetts, the corporations were called upon by a general law for annual statements of their doings and condition, which since then have been published as part of the records of the State. In some other states of the Union, however, no such returns have ever been required, and nothing is known of the affairs of the railroad companies, except what their officials see fit to make public. Neither has provision ever been made in Massachusetts, or elsewhere, to secure any uniformity in the books and the methods of keeping them, which lie behind the returns.

A system might indeed be prescribed by law, and in some cases has been, but the carrying out of the system is left practically in the discretion of the several corporations. Until the year 1873, the Massachusetts returns seem to have been accepted as they were sent in, and published for what they were worth without scrutiny or comment. It is consequently almost needless to say that they were worth very little. For years their preparation was regarded by those on whom it devolved as a mere formal task, in which accuracy was of little importance. Accordingly, the earlier series of returns will not bear the slightest examination. Their errors and discrepancies are gross and apparent. It is, for instance, quite out of the question to ascertain from them even how many miles of railroad there were in Massachusetts at any given time; an item of information, perhaps, as important as any, and one in respect to which accuracy would seem not very difficult of attainment. In the year 1873 a wholly new system was adopted. The returns as they came in were very carefully scrutinized, and explanations of all apparent discrepancies required. In this way, when the figures were published, though this Board in no way held itself respon-

sible for their real accuracy, they were at least plausible.

They are, however, still often inaccurate, and at times even deceptive. Indeed, wherever those in charge of a corporation have any object to gain by a concealment of the true condition of its affairs, these returns afford an excellent opportunity, amounting to almost an invitation, for either the suppression of the true or the suggestion of the false. They do so in a very obvious way. They are collected by authority of law and compiled by public officials;—they are prepared under oath and upon a uniform schedule of interrogatories, the answers to which are carefully tabulated. Under all these conditions the returns go out to the public with a species of endorsement of their truthfulness and accuracy on the part of the Commonwealth. They thus enjoy an authority which in no way belongs to them. In the popular mind it is naturally supposed that, as the results are uniform, the methods through which they are arrived at are likewise uniform, and it requires very considerable familiarity with railroad accounts to see that this is not the case. The returns of each road, on the contrary, are arrived at from a system of book-keeping peculiar to itself, through the application of arbitrary rules, which in different cases may or may not be the same, and which, in the case of corporations at all embarrassed financially, are almost certain to be exceptional. Under such a system it is in no way necessary to have recourse to fraud or misstatement in order to give to a company's affairs a desired aspect, whether favorable or otherwise. It can be done with perfect certainty, and yet the books be accurately kept and the results truthfully deduced from them. It is only necessary to apply to the real facts the arbitrary rules which each company lays down for its own guidance, and which do not appear on the face of the returns. The process is perfectly simple. The property of every railroad corporation consists of its road-bed and rolling-stock, and certain outside assets of uncertain value; its income is derived from its business as a common carrier, and the greater part of it is necessarily expended in carrying that business on. Any balance over and above the amount thus expended constitutes the net earnings of the road. What the amount of this balance is, or may be made to seem to be, depends within very wide limits upon the arbitrary rules under which the accounts are kept. What in one case is charged to construction may in another case be charged to current expenses, or the reverse;—the cost of renewals may be discontinued, and the property allowed to deteriorate; or a certain amount of current indebtedness may be suffered to accumulate, and the unpaid vouchers be carried over from one year to another. Through any, or all of these processes, a road on the verge of ruin may be made to appear in a flourishing condition; and, side by side with it, a road choked with remunerative business may be represented as daily going behind-hand. Yet all the while each return will be accurately drawn from the books, and, what is more, the officials of each company may very honestly consider that the returns made by them are the more correct in principle. Indeed, discretion and good judgment enter so largely into railroad accounting, that it has been in no way unusual for corporations to find themselves hopelessly bankrupt before those who managed their affairs were aware that they were in a position of danger.

The degree to which the balance representing net earnings may be apparently increased or diminished at will can be perfectly illustrated in a matter of now almost daily experience—the replacing of iron by steel rails. Of two corporations engaged in doing this, one is embarrassed and wishes to increase its apparent income; the other is pursuing a conservative course and is improving the value of its property. Each must lay down some rule under which the unusual outlay for steel in place of iron shall be entered on its books. The embarrassed corporation so manipulates the account that the whole outlay is ultimately charged to construction; while by the conservative corporation it is met at once out of its net earnings. When the cost of the steel is thus disposed of, the old iron still remains among the assets of the two corporations,—piled up along the track awaiting a purchaser. It must, therefore, appear in their returns as property on hand. One corporation charges it off its books as so much

material on hand required for use in yards, sidings, etc.; while the other will estimate it, not at its market value, but at its original cost, on the ground that it is still fit for use. Thus, by a simple and perhaps not dishonest manipulation of accounts, in a way which is not apparent on the face of the returns, a corporation which is doubling the value of its property may prove itself unable to pay a dividend; while another corporation on the highroad to insolvency may figure out a heavy surplus.

It is these returns, however, which now practically give to the stockholders as well as to the public all the insight they get into the condition of the railroad companies. The affairs of these corporations are so complicated and vast, and their constituency is so numerous and scattered, that the private investigations once possible are now out of the question. It is very difficult even for directors themselves to make them; impossible for any one else. Yet railroad securities are quoted and bought and sold in a way which was formerly peculiar to government bonds. The returns being, then, the only source from which information as to the value of these securities is to be had, they are, nevertheless of little value in the hands of one not accustomed to railroad accounts; while one familiar with the tests to be applied to them can make them produce thoroughly inconsistent results. Take, for instance, the test most commonly accepted,—that of the cost of running a train one mile, —and let it be appled comparatively among a number of not dissimilar roads. Into this cost enters all the expense of operating the road;—when it is returned at a large amount, it indicates that the company is putting its net earnings into its property; when it is very small, it indicates that the company is running down its property in order to make a favorable balance,—in other words, that it is living on its capital.

The accuracy of any result arrived at through the application of this test, necessarily depends, in the first place, on the correctness with which the mileage account is kept, and upon what in each case enters into it. That, again, is decided by arbitrary rules. Some corporations make the computation in one way, some in another. Take, for instance, the allowance for construction trains and switching-engines on the several Massachusetts roads. An examination of the replies to the special interrogatories, will show at a glance how widely these allowances vary. Among the roads leading out of Boston, for instance, one makes no account of the miles run by its switching-locomotives at all; while another enters them at 5 miles an hour, another at 6, and still a third at 7. The Fitchburg road, then, allows for them 50 miles apiece for each day, and the Boston & Providence 163. Presently another company renders a return in which they enter for the distance they actually run, the engine-driver being supposed to keep an account. In the first place, therefore, there is no uniformity in the mileage account, upon which the value of the test depends. Accepting it, however, as the best attainable, it remains to apply it to the Massachusetts returns.

The true average cost of running a train one mile,—the standard cost for purposes of comparison,—may be arrived at with approximate correctness by taking the average of six of the Boston roads,—the New York & New England being excluded on the one side and the Boston & Providence on the other, as exceptional roads. The average cost of running a passenger train one mile is found to be $1.15, and that of running a freight train is $1.30; the average cost per train mile run, is $1.106. The test will be found applied in the accompanying table to the returns of fifteen railroad corporations for the last year. In the case of each corporation the total train mileage returned by it is multiplied by the standard cost of running a train one mile, and the result shows how much it may be assumed to have cost such company to operate its road during the last year. The next column contains the cost of such operation as actually made up from the company's books. The difference between the two may be taken to roughly indicate the policy of the several companies in regard to maintaining or depreciating their property during the year. It will be seen that the cost of running a train one mile varies 130 per cent.; that it ranges from 60 cents to $1.41; and the inference is irresistible, that, while some corporations

are using up their property year by year, others are accumulating it with equal rapidity. A small margin of difference is natural, and calls for no explanation. That it should cost the Old Colony 2 cents more or less per mile to run its trains than it does the Boston & Albany, is small matter for surprise. That it should, however, cost the Fitchburg 32 cents more per mile run to operate its road than it does the Boston & Maine; or the Eastern 42 cents less than the Boston & Providence; or the Boston, Clinton & Fitchburg 36 cents less than the Providence & Worcester,—these are discrepancies which can be accounted for only in one way. What that way is, may be inferred from the figures in the third, fourth and fifth columns of the following table. These columns show both what it ought to have cost these companies to operate their roads during the year, and what it is claimed that it actually did cost them:

	Cost per train mile as returned.	Standard cost per train mile.	Total cost of operation as per return of company.	Cost of operation at standard cost per train mile.	Excess or deficit of standard cost, as compared with cost reported in return.	Percentage of excess or deficit of standard cost, as compared with cost in return.
Boston & Providence	$1.417	$1.106	$1,134,021 89	$885,097 51	+$248,924 34	+28
New York, New Haven & Hartford....	1.360	1.106	2,727,397 96	2,216,492 57	+510,905 39	+23
Connecticut River...	1.273	1.106	419,679 65	364,484 51	+55,195 14	+15
Fitchburg	1.330	1.106	1,326,501 56	1,102,784 86	+223,716 70	+20
New York & New England.....	1.161	1.106	766,620 11	730,021 94	+36,598 17	+5
Eastern.....	.994	1.106	2,069,871 61	2,303,501 59	−233,629 98	−10
Boston, Clinton & Fitchburg...	.832	1.106	718,314 75	954,575 33	−236,260 58	−25
Cheshire..... ...	.918	1.106	581,444 84	700,404 36	−118,959 52	−17
Springfield, Athol & North-Eastern	.605	1.106	59,981 14	109,668 75	−49,687 61	−45
Boston & Maine.....	1.011	1.106	1,594,986 77	1,743,691 95	−148,705 18	−8
Providence & Worcester.....	1.190	1.106	653,220 96	604,672 32	+48,548 54	+8
Nashua, Acton & Boston...	.685	1.106	44,145 60	71,252 94	−27,107 34	−38
Worcester & Nashua.	1.077	1.106	336,079 21	345,020 02	−8,940 81	−3
Old Colony.....	1.119	1.106	1,553,744 40	1,534,553 99	+19,190 41	+1
Boston & Albany....	1.094	1.106	5,371,902 88	5,429,592 89	−57,690 01	−1

A similar difference of system among the several corporations is made apparent by a comparison of the cost at which their rolling-stock stands on their books. The variations are so wide as to be almost ludicrous. The explanation is again found in the fact that each company is a law unto itself. In one return, a number of new engines or cars made in the shops of the company during each year are charged as part of the expenses of operation, on the ground that they roughly represent the general deterioration of the rolling-stock. In another case, it will on examination be found that every addition to rolling-stock is charged to construction, and that old numbers are carried on the books long after that which they once represented has been condemned for deterioration. The present cost of a new, first-class 8-wheel locomotive weighing 30 tons is $8,000; that of a new, first-class passenger car, complete, is $4,600; while a box freight-car costs $700, and a flat or platform freight $5.75. On the books of the companies it will be noticed that locomotives vary from $2,507 to $12,-

565 ; passenger cars from $96 to $4,500 ; and freight-cars, box and flat (in the way the returns are made, the value of these cannot be separated), from $57 to $868.

Again, as respects passenger mileage. From this item in the returns are necessarily deduced, not only the statistical results in regard to accidents, but also the rates at which passengers are carried. In making it up, however, the several companies each have their own system. Among the Boston roads, six out of the eight altogether exclude from the aggregate passengers traveling on free passes, and many of them apparently do not even keep a record of the free passes issued. Two of the eight, however, are more particular ; and while this class of passengers appear in the returns of the Boston & Albany road as having traveled 1,642,513 miles, they appear in that of the Fitchburg for the larger amount of 1,814,248 miles.

The system now in use is, however, open to far greater objections than have yet been advanced. Its worst feature is the opportunity it presents for the practical falsification of accounts under great temptation to falsify. It renders not only possible, but usual, the most extraordinary and unwarrantable liberties with the principles of book-keeping. The construction account of a railroad corporation, for instance, is supposed to represent what its property cost,—the money actually put into it,—and what accordingly it is approximately worth. As a matter of fact, however, in not a few cases almost everything finds its way into it,—not only bad debts and discounts, but even interest and losses. Consequently, the more certain corporations lose and the heavier the discounts to which they are subjected as borrowers, the more their property appears to be worth.

There is but one remedy for such a condition of affairs ; that, however, is a very obvious one. It will be found in an increased publicity and more perfect uniformity. The last vestige of the old idea that the accounts of railroad corporations are matters of private concernment only, and as such can best be managed, in secret, must be gotten rid of. To bring about this result, a bill was prepared a year ago, and submitted by this Board to the joint legislative committee on railways. It was meant to be radical in its character, having been prepared in the full light of the many and notorious railroad scandals of the last ten years, and with the financial revelations which followed the crisis of 1873 still fresh in mind. It subjected the books of the railroad corporations to a constant and regular public supervision, with a view to securing accuracy and uniformity in the methods of keeping them. The results set forth in future returns were to be not only plausible, but they were actually to represent the exact condition of the affairs of each company, not only in themselves, but as compared with those of every other company. Where charges had to be apportioned under arbitrary rules, those rules were in all cases to be approximately the same. Where, under exceptional circumstances, deviations from those rules became necessary, attention was to be called to them as such.

The measure was considered by the committee, but no action was taken upon it. Finally, towards the close of the session, it was referred back to the Board with instructions to further consider the whole subject and to report to the legislature of the present year. (Resolves of 1875, chap. 67.) In accordance with these instructions, a new draft of a measure regulating the whole subject of railroad accounts and returns has been submitted. The bill is founded on the two fundamental principles already referred to,—uniformity and publicity, and is believed to sufficiently explain itself. It is proposed to no longer rely on answers to interrogatories derived from books privately kept by different methods and under numerous and dissimilar arbitrary rules ; but, instead of that, to cause the accounts of the future to be so kept that the returns when published shall be understood to mean what they say. On the other hand, it is not intended to establish any public auditorship over the railroad corporations, nor in any way to dictate to them as to how they shall spend their money. Nothing at all of this sort is contemplated. They will hereafter, as now, be at perfect liberty to dispose of their means in whatever way, wisely or unwisely, they see fit; only the disposition they make of it is to appear

distinctly and visibly in the returns, with a view to its being generally and correctly understood.

Should the measure now submitted, or any suitable substitute for it, become a law, the Commissioners are prepared to state exactly the course they propose to pursue. Under any effective measure, some one, presumably this Board, must be authorized to prescribe a system. To secure the most acceptable general result, the Commissioners would, at a suitable time, call together the representatives of the various roads, and request them to select from their own accountants a committee to prepare and report on a common system of book-keeping, with a body of rules for securing the utmost attainable uniformity in entries. This could better be accomplished by those representing the corporations themselves, than by any outside authority; and it is of comparatively small importance what system or what rules are fixed upon, provided they be uniform and intelligible. A general supervisor of railroad accounts would then have to be appointed. As the voluntary and friendly cooperation of the railroad corporations is of the utmost importance in this matter, and, indeed, essential to an early success, this appointment also should, if possible, be made acceptable to them. If they could agree in recommending a proper and competent man, he should be appointed. These preliminaries accomplished, it would only remain, on the first of next October, to set the machinery in motion. Thereafter, new questions must be settled as they present themselves. The aim of the Commissioners would, therefore, be to have this reform practically brought about by the voluntary action of the corporations; the law merely giving a necessary motive to it, and the Commissioners acting as the medium through which it may be rendered certain that some action will be had.

There would seem to be but two sources from which any oposition to a reform of this character can be anticipated. It may come from those whose past or future operations it would expose to a scrutiny they cannot bear, or from the vestiges of private railroad conservatism. Objections from neither source would seem to be entitled to any weight. Meanwhile, the whole body of legitimate investors in railroad securities are most directly interested in a movement so calculated to save them from a repetition of the frequent and scandalous disasters of the past. The public is not less directly interested in having that accurate information of the doings and conditions of its transportation agencies which is now impossible to procure. Finally, all honest and well-disposed railroad officials and directors are interested in the development of a system which will render fraud difficult, and and give to each company and its management such credit as is justly its due.

WHAT IS STEEL?*

By A. L. HOLLEY, C. E.

From "Engineering and Mining Journal."

The general usage of engineers, manufacturers and merchants is gradually, but surely, fixing the answer to this question. In every country rails, boiler plates and machinery bars, whether hard or soft, are almost universally called steel, when they are made from *cast ingots*. Other names for the softer steels, such as homogeneous metal," "Bessemer iron," "Martin iron" and the like, have failed to obtain general recognition.

The meaning of the term steel, before it was enlarged to cover newly developing varieties, has been traced, by a recent writer, down through Percy, Shakspeare and the Bible, in a most interesting manner, from an archæological point of view. Undoubtedly, it did characterize hardness and other qualities imparted by carbon. It is within the memory of most of us, that all steels were tool

* A paper read before the American Institute of Mining Engineers.

steels, and that the soft, structural varieties were introduced—varieties which harden but little, which bend cold, and which, in many physical properties are akin rather to wrought iron than to tool steel. But, since both the hard and the soft steels are made by the same processes, and have their great, distinguishing structural feature in common, viz.: homogeneity resulting from fluidity, it has come to pass, despite every other proposed nomenclature, that all the compounds of iron which have been cast in malleable masses, are called steel, the term wrought iron being still confined to malleable iron made from pasty masses, and hence laminated in structure.

No inconvenience has been found, so far, in distinguishing between the more or less carburized products, in general, by the terms "high steel," "low steel," "tool-steel," &c., and, in particular, by prefixing the percentage of carbon and other ingredients, to the term steel. Steels which contain distinguishing ingredients, other than carbon, are called "chrome-steel," "titanium-steel," and the like, just as variously compounded bronzes are called "phosphor-bronze," "aluminium-bronze," &c. Thus the combination of several words or symbols, and figures, may completely disclose the characters of the metal, in terms that are subject to no misunderstanding.

But inasmuch as several high metallurgical authorities and clever writers have of late proposed to disturb this natural and somewhat settled nomenclature, it seems important to consider the claims of the various classifications. I shall attempt, in this paper, to show that the existing classification is more scientific and more convenient than any other, and those others which have been most prominently brought into public notice are radically defective.

(1). The most common objection to the existing enlargement of the term "steel," so as to include the soft steels, is that it "pirates" a time-honored term, and applies it to a thing which is very different in many of its qualities. People who know nothing about steel, except as they use it in cutting instruments or read about it in classic authors, say that it is brittle, hard and resilient, and they are much shocked to hear that it may also be soft and ductile; just as any one who knows nothing about indiarubber, except in the form of springs, would be astonished to find that one change in manufacture turns it into waterproof clothing, and another, into hard, crystalline instruments and jewelry. The terms "hard rubber" and "soft rubber," as used in technical literature and commerce, have not given rise to any serious misunderstandings. People who do not know that the great bulk of the material made by steel processes, and having every ingredient and structural arrangement of the old steels, is, nevertheless, soft and ductile, and that it would be unsuitable for rails, plates, and the like, if it were not soft and ductile, are not to be considered authorities in this discussion, any more than a painter in coal tar, would for that reason be an authority on analine colors.

Where a material is gradually developed into new forms and qualities, there must be some general name to cover the various classes of metal; and whether it is better to enlarge the boundaries of the old one, or to arbitrarily make a new one, which new one must, from the nature of the case, merge into the old one, there being no natural dividing line, will be further considered throughout this paper. I venture to assert here that the charge, specially brought by the inventors of new definitions, against the existing use of the term "steel"—the charge of upsetting the recognized order of things—is wholly without foundation. Nobody *invented* the term "steel," as applied to the soft homogeneous products. There has been no natural or obvious place in the gradual gradation from hard to soft steels, to inject a new definition. As the possibilities of the crucible process were enlarged, the first soft product was hardly more than a variation from standard carburization; the early Bessemer and Martin steels, as produced in a successful commercial way, were hard, and, in fact, it is only quite recently that refractory materials have been adopted, by means of which the slowly receding standard of carbon in cheap steels, has reached a tenth of one per cent. The same general name has been thus necessarily preserved, for the products of the same process, but its boundaries have been enlarged to admit new varieties, and a gradual growth of sub-classifica-

tion. So that whatever the merits of any arbitrarily devised nomenclature may be, it must bear the demerit, whatever that is, of upsetting existing order and developments.

(2). A more common form of this objection is that a blacksmith would not recognize the soft metal as steel. "A blacksmith," it is said, "calls that steel which will harden and temper, and blacksmiths ought to know what steel is." There are various answers to this objection :

I. If familiarity with soft, coking coal teaches a blacksmith how to burn highly carburized anthracite in his smithy, then his knowledge of highly carburized tool-steel ought to teach him what soft steel is. Hard coal is none the less coal because it does not respond, like soft coal, to a blacksmith's coking process, nor is soft steel any the less steel, because it does not respond like tool-steel, to his hardening process. Anthracite coal was introduced long after bituminous coal was in general use, and the "pirating" of the time-honored name "coal," to describe this material which is so different in many of its qualities, has not led to any vast inconveniences. It may be said that the parallel is incomplete, because both hard and soft coals are really the same thing only changed in composition and structure by natural processes, and that they both respond to the practical test—the influences of heat and oxygen. So are hard and soft steel the same thing, only changed in composition and structure by natural laws ; and so do they both respond to the influences of heat and oxygen. Coals are, in fact, more diverse than steels in their carburization, structure and strength, and in their requirements of treatment. If old nomenclature is to be held as a final criterion, then the modern condensing steam-engine should be a "low-pressure engine." The fact is, on the contrary, that it is as often "high pressure" as any non-condensing engine.

The determination of previously unknown intermediate forms and functions is constantly enlarging the boundaries of all general classifications, and introducing sub-divisions ; hence the criterion of old classifications is inadequate and worthless.

II. If hardening in water is the determining characteristic of steel, who is to define "hardening?" As a matter of fact, all products of the crucible, Bessemer vessel, open-hearth furnace and feeding-furnace, containing about a quarter of a per cent. of carbon, will perceptibly harden in water, just in proportion to the carbon contained ; and every one of them, however little carbon it contains, will harden in some degree, so far as existing tests can determine. If the product will make a tool, it is steel," says the blacksmith. What kind of a tool? Is an agricultural tool iron, and a cold chisel steel ; or does steel begin between cold chisels and razors, and if so, where? A water-hardened tool perfectly adapted to certain uses may be made of Bessemer steel containing half a per cent. of carbon. The same Bessemer ingot may make a good rail. If one-half the ingot is steel, why is the other half iron? The line must be so defined that people will agree upon it. Does it lie between thirty hundredths and thirty-one hundredths of carbon, or between ninety-nine hundredths and one per cent ?

Obviously, no two men can agree on the amount of any hardening element which may constitute steel. And if they could agree, it would only be after a quantitative analysis had been made in all close cases.

III. A recent writer makes a number of ingenious objections to the use of the word "steel" for all compounds of iron which are cast into malleable masses.

I. The term "steel" is said to be so vague that some words must be added to it to indicate the very dissimilar classes of steel, and the necessity for this explanation is deemed objectionable.

This objection is best answered by its author, who says that it is desirable to discriminate between the different classes of iron, and proposes the following brief and convenient nomenclature :—"Cast steel, welded steel, homogeneous wrought iron, homogeneous iron, welded wrought iron, puddled steel, puddled iron, blistered steel, Bessemer steel, Bessemer wrought iron, open-hearth wrought iron, Uchatius steel, Uchatius wrought iron, crucible steel, crucible homogeneous iron, &c." This classification, he says, shows whether the metal

"has the properties given by carbon." Now, every one of these metals has properties given by carbon. The percentage of carbon must be mentioned anyhow, so why not briefly say twenty-carbon steel or forty-carbon steel, and so denote both its carbon value and its homogeneity?

The objection, in its common form, is that the one word "steel" does not, without further explanation, define the various classes of metal referred to. Neither do the words "oil" "coal," "rock," "brass," nor great numbers of general names express the sub-classes referred to; nor can any word or any simple sentence define them all. The objection holds equally against all possible general classifications, and the only way to avoid it here is not to have any general classification in the iron business.

II. The writer referred to objects to calling the soft homogeneous compounds "steel" because it is sometimes difficult to tell whether they were made from cast or from pasty masses. It is true that a well-worked puddled iron, rather high in carbon, and a low steel with about the same carbon, cannot be distinguished very easily by means of ordinary observation and simple tests.

I will, in answer to this objection, quote the same writer, who admits the impossibility of any perfectly adequate definition by saying that "classifications are based on important differences between the classes they separate, and not on the facility of distinguishing those classes sharply." Now, there are important structural differences between puddled irons and cast steels which look alike—differences which will make themselves known after sufficient stress and wear; but is the difference between two steels varying only by a hundredth of a per cent. of carbon, one of these "important differences," upon which an adequate classification may be based?

The real answer to the objection, however, is this:—Admitting, for the sake of argument, that a considerable range of wrought irons and low steels cannot be distinguished by the observation of their fracture, nor by bending, nor by the usual quick mechanical tests—people do not largely purchase iron and steel by sampling individual pieces, as they would cigars; they purchase by specification of *manufacture;* for instance, the Pennsylvania R.R. Co. specifies 0.35 carbon steel for its rails, meaningly "steel," that it shall be homogeneous or cast; and from 0.30 to 0.40 carbon is recognized by makers and users generally as the proper percentage for rails. I note this fact here to correct the writer whose objection I am quoting. In trying to explain away the fact that such rails are recognized as steel, he says: "Railway managers do not care much about the degree of carburization of rails said to be steel, provided they are absolutely weldless."

The practical usefulness of a name does not, therefore, lie so much in its discrimination between metals after they are made, as in specifying the method and quality of their manufacture. Rails, plates, bars, and iron and steel generally are ordered on the understanding that they shall be fabricated by processes and of ingredients which are known to have yielded certain endurances to long continued stress and wear. If purchasers themselves do not specify the ingredient and processes they want, they specify a name and grade of metal, such as "0.60 carbon Martin steel," which refers the manufacturer to such ingredients and process; so that the name completely meets the requirements of the case.

Supposing even that it should be, not difficult, but impossible to distinguish between certain grades of steel and wrought iron by the most searching mechanical and chemical analyses—it can probably be determined in all cases from synthesis. Lawsuits arise as to the composition of material substances about which we have no synthetical record, such as a late suit about a certain paving stone, based on the question as to whether it was trap-rock, or a sandstone altered by the trap-rock that flowed over it. But there are almost always sufficient records of manufacture to determine whether a metal has been cast or welded. This, however, is an extreme case; perhaps it is one that could never occur. Destructive tests, can, I believe, determine in every case whether a metal was cast or welded. In the great majority of cases the most simple tests can distinguish iron from steel, as at present defined, so that practically the existing classification is entirely adequate.

III. The writer we are quoting misinterprets the current definition of steel, as calling for a product which is *better* than wrought iron; and then he attacks the definition by saying: "Who would call cold-short Bessemer ingots, on the whole, superior to the best Swedish iron?" Now as cold-short ingots are altogether *nil* until they have been reconstructed, we must admit that "a living dog is better than a dead lion." The bearings of his observation do not lie in its application.

IV. Another objection from the same source, that the current definition excludes certain classes of iron heretofore called steel, such as "blistered steel," "puddled steel," &c.—is at first sight a valid one. But should not the same objection also be valid against the old and limited meaning of the term "steel"? Does the mere fact that "puddled steel," so called, is carburized more than the usual products of the puddling furnace, although less than tool steels—does this mere fact of a little more carburization really define steel, according to the old restrictions of the term, despite the fact that the product, so called, has a totally different structure which renders it unfit for tools and for most other things that steel is used for? If, then, the term "puddled steel" should be excluded under the old classification, surely the classification now current must not be held responsible for its exclusion.

V. Again, classing homogeneous irons high in carbon and those low in carbon, under the same name—"steel"—is objected to, because the range of properties and uses due to variations in carbon, are much greater than those due to variations in homogeneity. Hence the classification, it is said, should be based on carbon and not on homogeneity. Every malleable iron, whatever it is called, contains carbon in some proportions, from a trace to the highest attainable solution, and since these combinations and the properties they impart, form a regular series of variations, running into each other, there can be no general carbon classification, except by drawing an arbitrary line at some carbon percentage. Now (1st) as the irons for some distance on both sides of this line cannot be thus distinguished, except by minute analysis in every instance; (2d) since synthesis, which is the practical matter, cannot be based on a carbon specification alone, because it would omit the vital feature of homogeneity, upon which depend, for instance, the advantages of steel rails over iron rails; and (3d) since a classification based on homogeneity furnishes means for distinguishing between products, while it also affords, with the addition of the carbon percentage, a perfect basis for synthesis—for these reasons I fail to see why a carbon basis, which must be arbitrary and revolutionary, could be useful or desirable. (4th) No less prominent an authority than Whitworth has proposed to divide wrought iron from steel at the point of twenty-eight tons tensile strength. This classification is open to all the objections we have urged against the equally unnatural and arbitrary carbon classification. How would Mr. Whitworth like to order gun-steel by this definition? Any steel-maker can produce a metal so full of phosphorus and silicon that it will fly into pieces under a sudden blow, and yet it will stand over twenty-eight tons statical pull. A steel made with very small proportions of carbon and manganese, to the almost entire exclusion of phosphorus and silicon, would safely stand the severest blows, and stretch perhaps thirty per cent. before breaking, but still it might barely reach twenty-eight tons tensile strength. A puddled iron totally unfit for guns, plates and rails, might stand twenty-eight tons statical tension, while the most pure and costly product of the crucible might fail under it. The former, according to this classification, would be steel—the latter wrought iron. (5th) It has been stated that what is known as "malleable iron" will confuse the existing classification. Seeing that iron is remanufactured into malleable iron by a subsequent process, and not cast while in a fluid state into a malleable mass, as our specification demands, this objection is absurd. Without answering the more trivial objections, let us consider what we are to do if we give up the existing classification.

I. The old and restricted term "steel" indicated certain properties, such as resilience, hardness, &c., in an indefinite degree, which were imparted by that indefinite amount of carbon which gave hardening and tempering qualities. Now

what shall we call the structural steels? We cannot call them wrought iron because they have all the enumerated features, even hardening and tempering in a gradually lessening degree, as carbon is diminished; and the features are not characteristic of wrought iron. Besides, wrought iron totally differs in feature of homogeneity, and is rapidly growing out of use to make room for the homogeneous compound.

II. We may call these compounds "homogeneous iron," but we must then add the percentage of carbon, and designate them as "ten-carbon homogeneous iron," up to, say "fifty-carbon homogeneous iron," for there is a vast range of grades and uses between these carburizations. Now, is it not easier to say "ten-carbon steel" up to "one hundred and fifty carbon steel," thus including all the varieties of ingot metal? And is the general public likely to agree that "homogeneous iron" means metals made from ingots, up to a certain arbitrary point of carbon, which nobody can determine without analysis, when beyond this point, ingot metal, made exactly in the same way and by the same furnaces and processes is "steel"? The inconvenience of such a nomenclature is illustrated by certain streets in London, which are called by one name up to a certain number, and by another name the rest of the way—a very inadequate illustration, for one can sometimes find a label on a street, without making a quantitative analysis.

6. As the author referred to, whose objections I have endeavored to answer, has offered, not dogmatically, but for discussion, a new definition of steel, and has advocated its claims with much learning and ingenuity, I think we ought to examine it in some detail. He defines steel as "a compound or alloy of iron whose nodulus of resilience can be rendered, by proper mechanical treatment, as great as that of a compound of 99.70 per cent. of iron with 0.30 of carbon can be by tempering." This is substantially an arbitrary division at the carbon point, 30 per cent., of all malleable iron compounds, whether made by wrought iron processes or by steel processes. The chief reasons appear to be (1) that this division somewhat corresponds to the distinction made between wrought iron and steel at a time when there were no soft steels; (2) that the carbon point, 0.30 per cent., is a "somewhat critical point in the curve representing the degrees to which differently carbonized varieties of iron possess the properties which are most affected by carbon"; (3) that resilience being the chief attribute of steel, it should for this reason form a basis of classification.

I. It is difficult to understand why scientific men should be willing to sacrifice a natural classification, which has grown out of the necessities of the case, for one that is unnatural and arbitrary, on the ground that it embraces species which are unlike the earlier species, although of the same genus. It is hardly necessary to repeat what has been said again and again in the foregoing pages on this subject.

II. If the 0.30 carbon point is a critical one, which I have not practically noticed, and which, for the purposes of this paper, need not be discussed, it is stated to be a point in a *curve*, which must be arbitrarily placed, and not the point of an angle, which might distinguish homogeneous from welded masses.

III. As to resilience being the most important quality of steels, and for that reason the proper basis of classification, it is unnecessary to discuss this claim for resilience here. The question is whether the importance of a quality can make existence of that quality a definite basis of classification when it exists in both classes, gradually increasing in one and decreasing in the other, and being practically the same near the dividing line.

To sum up once more, the answer to this and to all the cases of arbitrary classification: Exact definitions must be based on differences which always exist in every form and phase of the materials defined, and not on differences which, however great they may be in certain forms and phases of the materials, run together at one point, and there cease to be differences. If we divide steel from wrought iron by an arbitrary line of percentage of any ingredient or of modification due to any ingredient, there must be some point at which the difference between steel and wrought iron is infinitely small. If, however, we define steel as a compound made homogeneous

by fusion, while wrought iron, although the same in composition, is heterogeneous from welding, there is always and at every grade of the respective materials, a large and radical difference. Casting fluid steel and welding pasty iron are always distinct in their characters and results; they do not at any point shade into each other. The latter classification is, therefore, exact and complete.

IV. A very serious objection to the proposed division is that it occurs at a point about midway in the range of structural steels. It would be less inconvenient, though not less unscientific, if it divided the general class of structural steels from the more ordinary grades of tool steels. Of a pair of locomotive tires, both made by the same process, out of the same materials, and containing as nearly as practicable 0.30 carbon, one might be steel and the other wrought iron; or a pair of locomotive tires might both be steel, the one having been welded up from scrap and the other drawn from a cast ingot; or, one end of the same ingot might be steel and the other end wrought iron, the first having been hardened, and the other annealed. The convenience of such a nomenclature is not obvious at first sight.

The author of the proposed definition we are criticising has so vividly portrayed the disastrous confusion which would arise from changing a settled nomenclature that I can hardly do better than quote him in this connection. He says:—"It is a complete change in the meaning of a word that is in every man's mouth—a change in which the interests of the whole civilized world are affected, and in contemplating which the convenience of all mankind is to be considered. The natural conservatism of language would prolong this painful period of change to a most unpleasant length. Moreover the confusion would not end till the change had been well established in the other languages of the civilized world. In meeting the word 'steel' in specifications, contracts, and, indeed, all literature, whether technical or not, whether English or foreign, it would be necessary to determine whether it had been written before or after the change had been effected."

In conclusion, it seems hardly necessary to *again* sum up what has been chiefly a reiteration in different forms of answers to criticisms on the present enlarged use of the term "steel," and of the one great objection to the nomenclatures, that they are fatally indefinite. The names of new materials and processes, like the laws of trade, are not fixed by the arbitrary edicts of philosophers, but they are gradually developed to meet the general convenience.

A BALLOON WITH POWER.

From "The Builder."

On the 2d of February, 1872, M. Dupuy de Lome made a satisfactory ascent from Paris in a balloon constructed by him, and provided with a screw for propelling and steering it. The screw was then worked by manual power, and the rate of progress was comparatively slow. M. Dupuy de Lome expressed at that time his belief that its speed might be increased if, instead of the weight of the eight men working the screw, an eight-horse-power engine were taken into the car. The only drawback to such a plan was the liability of the engine to set the balloon on fire. According to a communication in the *Jahresbericht des Physikalischen Vereins zu Frankfurt*, 1875, an important step in advance in this direction has now been taken. Herr Hanlein, civil engineer, of Mayence, has invented and constructed a balloon driven by a gas-engine. He has proved by his invention that, by increasing the size of the balloon and by other improvements, an increased rate of speed may be attained.

If we suppose a screw-steamer cut off just above the water-line, so that it moves only in one element, viz., water, that it finds its resistance in water, that the point of attack for its driving apparatus lies in it, and that its helm like-

wise acts there, this case is perfectly analogous to the movement of a balloon which may be driven and guided in the air. Of course, the driving apparatus of a balloon has to overcome a very much smaller amount of resistance than a vessel moving in water; but, in the same proportion, the resistance which a body propelled in the air meets with is less than when it is moved in water.

The impetus in boundless water or boundless air is calculated according to the formula:

$$P = \Sigma \cdot \frac{v^3}{2g} \cdot F \cdot \gamma,$$

in which Σ is a co-efficient depending upon the form of the body; v, the speed of the body; F, its greatest cross-section; γ, the density of the medium; g, the weight of the earth.

It will be seen from this formula that the impetus for congruent bodies, with equal velocity, depends solely upon the density of the medium in which they are immersed. The density of air being $\frac{1}{770}$ of that of water, the resistance a vessel propelled in air meets with, compared with that of another vessel propelled in water, is in the same proportion. In like manner, the pressure of the screw against air amounting to only $\frac{1}{770}$ of its pressure against water, and the resistance of the propelled body and the pressure of the screw being less, at the same rate, in air than in water, the final result, velocity, is the same.

Without (for the sake of simplicity of theoretical examination) taking account here of the coefficients modifying those relations, it may be said that the force necessary for moving a body in the air is only $\frac{1}{770}$ of the force which must be applied to move a similar body with the same velocity in water.

A like relation exists also between the bearing capacity of the balloon and that of the ship. A ship, for instance, the volume of which under water amounts to 1,000 cubic metres, has a bearing capacity of 1,000,000 kilometres, while a balloon of the same dimensions, filled with hydrogen, is capable of carrying only 1,250 kilometres, or $\frac{1}{770}$ of the capacity of a ship. The balloon motor absorbs in weight about the same percentage of the balloon's carrying capacity as the ship's engine does of the carrying power of the ship. Supposing a screw steamer and a balloon to have the same dimensions, the latter will require only $\frac{1}{770}$ of the power of the ship's engine in order to attain a speed equal to that of the ship. In this case, it is supposed that the effect of the air screw is equal to that of a water-screw. But as it is not possible to make the sides of a balloon as smooth as the sides of a ship, the meshes of the netting causing small bulgings, though only on the upper surface of the balloon, and thus increasing resistance to its movement, its speed will be proportionately less.

Hitherto there has been a want of motor in the use of which the weight of the necessary mechanism stands in the same proportion to the carrying power of a balloon as, for instance, the weight of the boiler with contents and fuel to the carrying capacity of a steamship. Hanlein, in the first instance, obtained a patent (in 1865) for the combination of an air-screw and gas-engine for the locomotion of balloons, and included in this patent the application of a smaller balloon, filled with air, which, in the interior of the balloon proper, served the purpose of preserving the form as well as the volume of the latter. The smaller balloon acts in two ways. As soon as the balloon reaches the higher strata of the atmosphere, the gas with which it is filled expands, expelling a corresponding quantity of air from the inner, smaller balloon. In the case of the consumption of gas for the supply of the gas-engine, the inner balloon expands by taking in atmospheric air by the action of an air-pump.

In 1870, Hanlein constructed his first model, with a length of balloon 38.94 ft. He was enabled to carry out his plans by the generosity of a few rich Frankfurters, who provided the necessary funds in the interest of science. The first experiments with the model were made in the following year at Mainz, and Hanlein's principle was found in practice not only perfectly sound, but it led to the conclusion that, with a balloon constructed on a large scale, it would be possible, by means of a gas engine of corresponding size, to attain a speed which would permit of overcoming, throughout the year, with few exceptions, the velocity of the wind. In 1872, Hanlein constructed a

second, larger, balloon, capable of carrying, besides the necessaay apparatus and outfit two persons.

This balloon, of the form of a rotatory body, with a longitudinal section like the water-line of a ship, has a length of 166.32 ft., and a diameter of 30.36 ft. The covering of the balloon consists of closely-woven silk, having a thick layer of caoutchouic inside and a thinner one outside. The ten strips forming the balloon are jointed perfectly gas-proof by means of strips 1.18 in. wide of a similar nature. The balloon is surrounded by a net, the meshes of which are 3.94 ft. square. Each mesh is connected from the terminal meshes of the sides with a cord 6.6 ft. long. Each twelve of such cords are united in a loop, and from each of these loops a stronger rope leads to the car. The back cords do not lead direct to the car, but unite at a strong cross-beam 15.84 ft. long, forming the space required for the play of the screw. All the ropes leading from the car to the net meet the balloon tangentially. To prevent the horizontal strain exerted by the front and back ropes upon the car, they are, running under the car, connected by other ropes diagonally with each other. Thus the whole weight of the car rests in a perfect network of ropes, the car being further suspended at a number of other points, thus reducing the strain upon the apparatus to a minimum. Between car and balloon, 18.15 ft. under the balloon axis, is a frame, of such a form that the ropes connecting the car with the balloon cross the frame tangentially, and thus may be fastened on to it. This frame carries the side-posts and stays supporting the steering-apparatus and cross-pieces for the transmission of the steering, and serves for a resting-point for four stays connected at their lower ends with the car. Two buffers, fastened underneath the car, protect the screw in case of the balloon touching the ground. All the supports, stays, &c., are made of very light soft wood, and are of the shape of fish-bellied bearers. They consist of four rods, which are held together by cross-pieces (crosses or rings) at intervals of 11.8 in.

Besides the usual inlet and escape valves for gas, the balloon is provided with two safety-valves, which open at a pressure sufficient to keep the balloon perfectly tight and extended. In the interior of the balloon is the smaller one, already mentioned, filled with air.

The gas-engine consists of two pairs of horizontal cylinders, acting upon a common crank-axle, by means of four cranks. Each two of them are opposite to each other, and form with the two others right angles. By this arrangement the pitching which would otherwise be caused by the forward and backward movements of the pistons is neutralized to a great extent. The screw is secured to the extremity of the crank-axle. The explosions are effected by the electrical spark of an induction apparatus. The engine is a Lenoir engine, its parts being made hollow, to reduce the weight of the whole. It makes ninety revolutions per minute. The diameter of the cylinders is 6.3 in. ; that of the screw, 15 ft. ; the pitch of the latter, 20 ft. The screw has four blades, and is in form like Griffith's screw. The sides and ends of the cylinders are surrounded by cold water, to prevent them from being too highly heated. As but little water can, however, be carried, it is conducted from the cylinders in so-called coolers along the car. In these coolers the heated water comes into contact with the air passing through them. An aliquot part of it evaporates as the rising power of the balloon diminishes in consequence of the consumption of gas. The cooled water is brought back to the cylinders by two pumps, driven by the engine. The cooling surface is large enough to ensure an ample supply of cooling water, about 150 lb. being a sufficient store. The engine takes the gas it consumes direct from the larger balloon. In proportion as the consumption of gas goes on, the inner, smaller balloon must be extended by air.

The cubic spaces of the balloon, as measured by a meter, is 25,922 cubic feet. From this, the carrying power may be calculated as follows :

	Lb.
If the balloon is filled with gas of 0.50 sp. gr., it is	3,128
If the balloon is filled with gas of 0.45 sp. gr., it is	3,440
If the balloon is filled with gas of 0.40 sp. gr., it is	3,756
If the balloon is filled with hydrogen gas it is	5,828.

The weights to be carried are :

	Lb.
Gas engine	466
Screw	158
Frames, cross-bearers, steering apparatus, buffers, &c.	498
Cooling apparatus	220
Car	248
Covering of balloon	700
Net, with ropes	293
Battery, with inductor	80
Water	150
	2,812

Supposing the specific gravity of the gas to be 0.45, there would remain 628 lb. for two persons and their equipment.

At the experiments carried on at Brunn, the gas used was so heavy that the car had to be considerably lightened before it would carry two persons. On that account a regular ascent could not be made, and the balloon was secured by ropes, and propelled by the engine a distance of nearly 2,000 ft. It was found that the engine acted perfectly satisfactory; the balloon moved with the wind, and against the wind, was propelled in a circle by means of the steering apparatus, and was perfectly manageable. In being propelled against the wind, a good rate of speed was attained. The engine consumed per hour from 70 to 75 cubic feet of gas, and from 20 to 25 lb. of cooling water.

It will thus be seen that, if all the parts are made still lighter, and lighter gas,—for instance, hydrogen gas,—is used, and the balloon is made of larger dimensions, a high rate of speed seems possible.

ON THE EFFICIENCY OF BELTS OR STRAPS AS COMMUNICATORS OF WORK.

By Professor OSBORNE REYNOLDS.

From "The Engineer."

It has often been remarked that it seems to be impossible so to construct belts that they shall drive without slipping. I am not aware that any reason has ever been given for this; but, on the other hand, most writers seem to have assumed that if the belt is made sufficiently tight, so that the tension on the slack side is from one one-half to one-quarter that on the tight side, according as the strap is in contact with one-half or the whole of the pulleys, it will not slip. The object of this communication is to show that not only is a reason to be given for this residual slipping, but that it follows a definite law, depending on the elasticity of the strap, and independent of its tightness over and above what is necessary to prevent it slipping bodily round the wheel.

When a pulley, A, is connected with another pulley, B, by a belt, so that A drives B, it is usual to assume that the surfaces of the two pulleys move with the same velocity, namely, the velocity of the strap; and that the work communicated from A to B equals this velocity multiplied by the difference in the tension on two sides of the belt. This law would doubtless be true if the strap were inelastic, and did not stretch at all under the tension to which it is subjected; but as all straps are more or less elastic, it can be shown that this law does not hold rigorously, although with such an inelastic material as leather it is not far from the truth.

Owing to its elasticity, the tight side of the belt will be more stretched than the slack or slacker side, and will, in consequence, have to move faster. This is easily seen when we consider that each point on the strap completes its entire circuit in the same time, so that if at any instant a number of marks were made on the strap at different points, these marks would all return to the same points in precisely the same time; for the velocity at each point would be equal to the length of strap which passes that point, and on the tight side this would be the stretched length, whereas on the other side it would be the unstretched length, and hence the two sides of the strap would move with different velocities, according to the de-

gree in which the strap is more stretched on the one side than on the other.

Now the stretching of a strap will be proportional to tension, although the degree will depend on its side and the material of which the strap is composed. Let $\gamma\ \pi$ represent the increase in length per foot in a certain strap, caused by a tension of π lb. Then, if π_1 and π_2 represent the tensions on the two sides of the belt respectively, the stretching on these two sides will be respectively proportioned to $\gamma\ \pi_1$ and $\gamma\ \pi_2$, and the difference will be proportional to $\gamma\ (\pi_1 - \pi_2)$. Therefore the velocities of the two sides will be in the ratio $= \frac{1+\gamma\ (\pi_1 - \pi_2)}{1}$.

Again, it is easy to see that the velocity of the tight side of the strap must be equal to that of the surface of the pulley A which drives it; whereas the velocity of the pulley B, which is driven by the strap, will be the same as that of the slack side of the strap; and hence the velocities of the two pulleys differ in the ratio $\frac{1+\gamma\ (\pi_1 - \pi_2)}{1}$. And since the turning effort of the strap on either pulley is the same, namely, $\pi_1 - \pi_2$, the difference of its tensions, the work done by A, which equals its velocity into this effort, will be greater than that taken up by B in the ratio $\frac{1+\gamma\ (\pi_1 - \pi_2)}{1}$. This excess of work will have been spent in the slipping, or more properly the creeping, of the strap round the pulleys. The manner in which this creeping takes place is easily seen, as follows:—The strap comes on to A tight and stretched, and leaves it unstretched. It has therefore contracted while on the pulley. This contraction takes place gradually from the point at which it comes on to that at which it leaves, and the result is that the strap is continually slipping over the pulley to the point at which it first comes on. In the same way with B; the strap comes on unstretched and leaves it stretched, and has expanded while on the wheel, which expansion takes place gradually from the point at which the strap comes on until it leaves.

The proportion which the slipping bears to the whole distance traveled by the strap $= \gamma\ (\pi_1 - \pi_2)$, which, as previously shown, is the proportion which the work lost bears to the whole work done by A. From this it appears that the slipping and work lost are proportional to γ, *i.e.*, to the increase which a tension of 1 lb. would cause in 1 ft. length of the strap; and hence, the more inelastic the material is, the better it is suited for belts.

The actual amount of this slipping may be calculated when we know the elasticity of the belts. With leather it is very small. One belt, which had been in use about two years, and was 1.25 in. wide and $\frac{1}{4}$ in. thick—the usual thickness—increased in length by sixteen-thousandths under a tension of 100 lb. From this example it appears that, for a leather belt of breadth b in.

$$\gamma = \frac{20}{100{,}000}\ \frac{1}{b}$$

Hence the ratio of slipping $= .0002\ \frac{1}{b}$ $(\pi_1 - \pi^2)$; and in practice $\pi_1 - \pi_2$ varies from 20 lb. to 60 lb. per inch width of belt; therefore the slipping $= .008$, or nearly 1 per cent. With new straps it would probably be more. With soft, elastic materials, such as india-rubber, the slipping is very much greater. In some instances I have been able to make the driving pulley A turn twice as fast as the pulley B, simply in virtue of this expanding and contracting on the pulleys. This shows at once how it is that elastic straps, such as can be made of soft india-rubber, have never come into use—a fact which is otherwise somewhat astonishing, considering for how many purposes an elastic connection of this sort would be useful. A similar explanation to the above may also be given for the friction occurring when elastic tires are used for the wheels of carriages and engines. The tire is perpetually expanding between the wheel and the ground. As the wheel rolls on to the tire, it is continually elongating the part between it and the ground which is in front of the point in which the pressure is greatest. This elongation can only be accomplished by sliding the tire over both the surface of the wheel and the ground against whatever friction there may be; and similarly, towards the back of the wheel, the tire is contracting also against friction. Even when there

is no tire, if either the wheel or the ground is elastic a similar action takes place; and hence we may probably explain what is usually called rolling friction, which has been observed to take place no matter how true or hard the surface of the wheel and the plane on which it rolls may be.

THE BAIE VERTE CANAL AGAIN!

By THOS. GUERIN, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

I HAVE read Mr. Herschel's communication to this Magazine of February last, which is intended as a reply to my article of January previous. He alludes to the errors contained in his late paper, and attributes the cause to the school in which he was trained; that school having never taught him to use units of more than one denomination.

With the exception of one passage, he does not attempt to dispute the accuracy of what was shown in my article of January.

In questioning the accuracy of that passage, he says: "How the table on page 56 of this volume of this Magazine is found, is still not clear.

"For example, if $v = n\sqrt[3]{r}$, certainly when $v = 76.10$ feet per minute $= 1.302$ feet per second, and $r = 1.612$ feet per hour, the $n = \frac{v}{\sqrt[3]{r}} = \frac{1.302}{1.173} = 1.109$, instead of 0.550 as given, and similarly:

"For $v = 38.56$ feet per minute $= 0.643$ feet per second, and $r = 0.945$ feet per hour, it would seem that n should equal 0.655, instead of 1.327 as given, all of which may be noted by future investigators."

Here, again, Mr. Herschel is in error as usual; for the table to which he alludes is entirely correct. I refer him to page 253 of Beardmore's Manual of Hydrology, from which the table was constructed. This is his own favorite book; it having been his chief dependence in his late attempt to annihilate myself; it is, therefore, reasonable to suppose he ought to be thoroughly acquainted with it. He will find it there stated that the mean velocity of the flood stream below New Shot Isle is 78.10 feet per minute, and the average velocity above New Shot Isle is 38.56 feet per minute.

The geography of the place will show him that Glasgow and Clyde Bank are above New Shot Isle; while Bowling and Port Glasgow are below.

His equation then will run thus: $n = \frac{v}{\sqrt[3]{r}} = \frac{0.643}{1.173} = 0.550$, as already given in the table. Similarly at Port Glasgow, the number 1.327 is correct as given in the table, and not 0.655 as Mr. Herschel erroneously makes it.

"He asks: "What shall the profession do with a formula whose mainstay coefficient bobs about, according to Mr. Guerin, from 0.550 to 1.3313, and according to me (as far as I at this time think it worth while to pursue it) from 0.655 to 1.3313?"

I am sorry Mr. Herschel is unwilling to comprehend the nature of the coefficient n. Once more and finally, I refer him to pages 241 and 242 of the September number of this Magazine for 1874; also to page 55 of the January number, 1875. He will there find that n does not "bob about," that it has been theoretically shown to be a constant quantity, that experiment has shown its value to be about $1\frac{33}{100}$, and that the value 0.550 is found in a locality adduced by himself in his paper to the American Society of Civil Engineers, and is foreign to the case; but the value 0.665 is not found in any case as is shown above.

It is puerile to answer any more such criticism as this. A few words more and I shall have finished with Mr. Herschel.

I compliment him on his profound knowledge of the Calculus as evinced in his description of my journey from Canada, and it may be that some one whose penetration is greater than mine can see its application to the subject in discussion. He refers to a friendly note he says he wrote to me in order to draw

out a discussion on this subject, but it was returned by the P. O. authorities, and endorsed "not found." He forgets, however, to mention another friendly note which he did write to me, and which I received, and have answered.

This last note was written to me before the publication of my last article, and after his having read the substance of that article in manuscript addressed to "The American Society of Civil Engineers." In this latter note he made a modest proposition which I declined.

If he preferred a private discussion, why did he publish the last extraordinary article? On the whole, it is manifest he thought, in the first instance, that he had found a means of refuting the article on "The Baie Verte Canal," as published in this Magazine in September, 1874, and on no account would he forego the golden opportunity of doing so publicly. The tone of his paper has shown this; for, however friendly that strayed note may have been, his paper commences by asserting that the article was "misleading"; was "a gross Hydraulic heresy"; was "an illusion"; was "an assumption"; there was "no such law"; it was "an absurdity."

Gentlemen who have read the correspondence that has taken place between Mr. Herschel and myself, will now see that those florid assertions recoil like the boomerang on the party who has used them.

CONDENSED AIR TRAMWAYS.

From "Nature."

For some weeks the North Paris Tramways Company has been trying on the line from Courbevoie to the Arc de l'Etoile a new system of locomotion, in which the motive power is compressed air. Some details of M. Mékarski's (the inventor) system are given in the *Revue Scientifique*. It is capable of considerable developments and of varied applications, since it has solved in a very satisfactory manner the double problem of the industrial production of air condensed to very high pressures, and of the storage of the air in reservoirs intended to discharge into a cylinder placed in any apparatus whatever, at any distance from the condensing pump.

The "Voiture Automatique" of M. Mékarski is characterized by the absence of an imperial, and by a platform in front and another behind. This car carries the reservoirs of condensed air, the apparatus for distribution, and the cylinders, M. Mékarski places under the truck of the car the sheet-iron cylinders, which contain the condensed air; on the front platform is placed the distributing apparatus which the engineman works; the two cylinders are placed, as in certain locomotives, outside the framework, horizontally, and act directly, by means of a crank, on the front wheels of the car. No doubt this arrangement might be advantageously modified; but the important point is the possibility of manufacturing compressed air in sufficient quantities to be of use as a motive power.

The condensing apparatus used by M. Mékarski consists of two pump-barrels of cast-iron, placed vertically, communicating respectively with two horizontal pump-barrels, in which move two pistons worked by a steam-engine. This is, in reality, a double condensing pump, the former bringing the air to the pressure of from ten to twelve atmospheres, and the second raising the pressure to twenty-five atmospheres. The pistons act upon a mass of water which compresses the air directly and absorbs by degrees the heat disengaged by compression. By an ingenious contrivance the supply of water is continually renewed, and the temperature thus kept down. But this arrangement does not absorb a sufficient amount of the heat disengaged, a difficulty which M. Mékarski has met as follows. The external air drawn into the pump raises a valve constantly covered by a layer of water of several centimetres; besides, a large cast-iron

tube, constantly traversed by the air already condensed and the excess of water, communicates with the two vertical pump-barrels; finally, the second pump is fitted with a tap by which the heated water escapes.

In M. Mékarski's automatic car the compressed air is stored, under the truck, in sheet-iron reservoirs or cylinders. The total capacity is about 2,000 litres; 1,500 litres serve as an ordinary supply; 300 litres constituting a reserve; the remaining 200 litres are intended to serve as a brake. The air is compressed in the cylinders to the pressure of twenty-five atmospheres. On the line from Courbevoie to the Arc de Triomphe, 7,500 metres going and returning, the resistance is unusually great. In one experiment the ordinary feeding cylinders contained 1,500 litres of twenty-five atmospheres at departure, and the pressure, on arrival, was not more than four and a quarter atmospheres. The expenditure had thus been about 1,250 litres at twenty-five atmospheres for a run of 7,500 metres, or 166 litres per kilometre.

But unless it is possible to heat the air gradually during its detention, and before it reaches the cylinder, unless, in fact, the heat abstracted in condensation be restored to it, the loss of power is very great. This has hitherto been the stumbling block of compressed air engines, and M. Mékarski seems to have completely met the difficulty. He adopts as a re-heater a cylinder holding about 100 litres of water, taken from the boiler of an engine, at five atmospheres, and to obtain the maximum of effect possible, the condensed air is delivered from the reservoirs to the cylinder only after traversing the entire mass of water.

By a clever contrivance M. Mékarski regulates at pleasure the action of the compressed air upon the piston. Two hermetically-closed boxes are placed vertically upon the re-heater; their common face is formed by a caoutchouc diaphragm, in direct connection with an obturator, which opens or shuts more or less the opening which communicates between the lower box and the chamber containing a mixture of compressed air and vapor in the upper part of the hot-water cylinder. It will be seen that this orifice will be more or less uncovered according as the pressure in the lower box will be above, or not, the pressure in the lower box. This second box is itself filled with air, and constitutes a small pump-barrel, in which a large plunger piston works. The rod of the piston is a screw, and is fitted outside with a small regulator, on which the driver works. This may rapidly be made to vary the presence of the air in the upper box, and consequently the pressure be increased or diminished of the air which is delivered from the lower box to the motory cylinder.

DESCRIPTION OF A SKEW-ARCH AT HARRISBURG.

By THOMAS M. CLEEMANN, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE following description of a skew arch bridge in the city of Harrisburg, which is built on a different method to either of those mentioned in the interesting papers on the subject which have just appeared in VAN NOSTRAND'S MAGAZINE, will perhaps form an interesting supplement to them.

State Street crosses the Pennsylvania Railroad at an angle of seventy-one degrees, and, in order to avoid a grade crossing, an iron bridge was erected over the tracks, and approaches made with a slight descending grade until the old level of the street was reached. The whole of the width beneath the iron bridge is filled with tracks, and the abutments are pierced with archways to accommodate foot-passengers. To illuminate these passages, a second arch was made in the walls separating them from the tracks, the two arches meeting in a groin, both being skew and intersecting at an angle of seventy-one degrees. Mr. Joseph M. Wilson, to whom the design is due, wished the smaller arch to form a

semi-circle on the face, of a radius of five feet, and the larger arch to form an ellipse of 17 feet span, and of course a height equal to the radius of the smaller arch. If the helicoidal method of building the arch had been adopted, as was at first intended, the joints on the face of the small arch would have radiated from a point below the centre, which was supposed to injure the appearance, and it was therefore made a condition that the face joints should radiate from the centre. With this limitation, the writer was instructed to make the working drawings, and supervise the construction. It occurred to him that it would not weaken the arch to make the following modification of the helicoidal method. Whereas in that method the crossing joints are generated by a line touching, as directrices, the joints of the soffit as found from the development, and the axis of the arch, and always perpendicular to the axis; there would be no objection to taking the same directrices, but introduce the condition that the generating should be always parallel to the face, instead of being perpendicular to the axis. This makes the crossing joints portions of the surface called a conoid in Warren's Descriptive Geometry, and which may be called for distinction a helicoidal conoid. It was in this manner that the arches were built. It should be remarked, however, that only the face stones of the two arches, the groin stones, and the skew backs, were made of stone, the rest was of brick, the joints running from face to skew back according to the joints drawn on the development of the soffit.

The smaller arch will be seen to be a high ellipse on the right section; that is, one in which the vertical axis is the longer.

It may be of some interest to describe in detail the mode of forming the templets, and what were required:

1ST. THE SMALLER ARCH.

The portion of the stones first dressed was one of the beds, and for this "twisting rules" were necessary. As the twist is the same for all the stones, but two pairs of them were required, one for the stones two feet long, and the other for the stones one foot long; these dimensions of stones having been chosen for convenience. One of the rules is an ordinary straight edge; the other has the addition of a triangle on the side, making it trapezoidal in shape. A draft having been cut on one edge of the stone, and the straight edge laid upon it, another is cut at the distance of two feet (for the stones of that length) and sunk until, when the trapezoidal rule is applied, the upper edges are in the same plane, observed by sighting across from one to the other. The intermediate stone is then dressed away with a straight edge. The next operation is to find the edge at the soffit. To do this, a templet is formed to the angle between the bending face joint and the soffit crossing joint, and being applied so that one side coincides with the draft previously cut at the face, the edge is marked off with the other side.

The soffit is then dressed along the edge by means of the arch square, the straight part being applied along the generating lines of the bed. The bounding lines of the surface of the soffit in each stone are marked with a templet got from the development, and made of sheet iron or zinc, so as to bend into the surface. The face can now be cut, two edges being given. Its bounding lines are next marked with a templet constructed from the elevation. The other bed is then formed with the twisting rules, and the remaining sides with the common square. Such being the process of cutting the stones, let us proceed to the mode of forming the patterns:

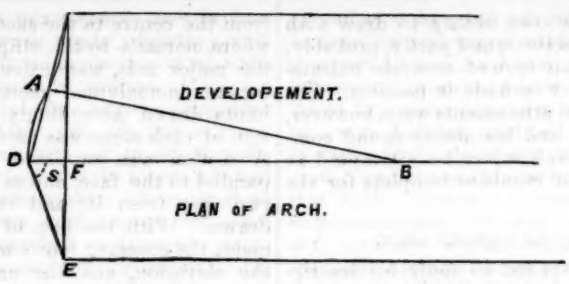
In the development we find AD equal to one half the curve of the face; the angle $ADB = \cos.^{-1} \frac{DF}{2AD} =$

$$\cos.^{-1} \frac{DE \cos. S}{2AD} = \cos.^{-1} \frac{10 \times \cos. 71°}{2 \times 7.854}$$

$$= 78° 02\tfrac{1}{2}'$$

And $AB = AD \tan. ADB = 37.083$.

The generatrix of the conoidal surfaces in passing along the line AB, if there were a joint there, would describe an angle whose projection on the face would be ninety degrees. The projection of the angle described when it passed over the distance two feet on the line AB, would be the angle for the twisting rules for the two feet long stones, and one half of it, that for the one foot long



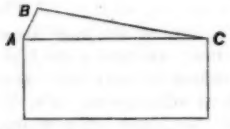
stones. We find it by the proportion, A B : 90° : : 2 : the angles required.

In making the rules, we assume them say two feet long; the distance I K

will be two feet multiplied by the angle found from the last proportion. The finding of the angle between the heading face joints and the soffit coursing joints, is a more complicated operation. Let us take the position of the generatrix at the face joints, and imagine a line drawn from the joint intersecting the axis at right angles; the length of this line can be found, being the square root of the sum of the squares of the abscissa and ordinate of the joint on the ellipse of right section. The generatrix and distance cut off on the axis are two other sides of a triangle, one being equal to the half span, and the other to the abscissa multiplied by tan. S. From this triangle we can deduce the angle between the generatrix and axis. We now take a second triangle in which one side is the generatrix in its primitive position, another is the length cut off on the axis in its progression to its second position, being in the same ratio to two as D B is to A B; and the included angle is the supplement to the angle between the generatrix and axis, just found; we then find the third side of the triangle. We are now prepared to find the angle required, it being in a triangle whose three sides are known; one being the side of the triangle just found, another the generatrix in its second position equal to the half span, and the third, the length of the stone, supposed two feet; the angle between the two feet side and the generatrix is the angle between the heading and coursing joint required. It is necessary to repeat this calculation for each angle of face stones.

The arch square is a piece of wood cut to the form of the soffit, with another piece attached in the direction of the radius produced. The mode of obtaining the templets for the soffit from the development, and for the face stones from the elevation, require no explanation. Two sides of these templets were made three-sixteenths of an inch less than the drawings gave, to allow for the mortar in the joints.

The skew-back stones were made in the present instance to run far enough into the arch to catch two courses of brick.



The dimensions of the shoulder are easily found

$$B C = \frac{A B}{\tan. B C A} = \frac{\text{thickness of two bricks}}{\text{cot. B A C known from the development}}$$

$$A C = \sqrt{\overline{A B}^2 + \overline{B C}^2}$$

The student of descriptive geometry would be surprised, perhaps, that the tedious operation of solving three triangles for finding each angle between the face joints and coursing joints was pursued, when the projections can be easily constructed upon the drawing, and finding the angle is then one of the simplest problems of descriptive geometry. The writer adopted the method of calculation, partly because his drawing was small, and he has small confi-

dence in his own ability to draw with sufficient exactness, and partly, probably, from an innate love of accurate calculation whenever he finds it possible. His mathematical attainments were, however, sorely tried, and his ability found completely at fault when he attempted to calculate the requisite templets for the larger arch.

2D. THE LARGER ARCH.

Being compelled to apply his descriptive geometry to finding the necessary bevels for this arch, in order as much as possible to avoid errors of construction, he determined to make the drawings full size. He therefore obtained a sufficiently large space in the Company's Carpenter Shop, and constructed the projections on a prepared floor. Having drawn the ellipse, and marked on it the positions of the joints and measured their abscissas and ordinates, the distance from the centre to the successive points where normals to the ellipse would cut the major axis, were calculated by the formula in analytical geometry, and the joints drawn accordingly. The elevation of each stone was then constructed. A section was supposed to be made parallel to the face, and at a distance of two feet from it, and the projection drawn. With the help of the development, the crossing joints were drawn on the elevation, and the angle between them and the heading joints found by passing a plane through them and revolving it about its trace in the vertical plane until it coincided with it, when the angle could be measured, according to a simple problem in descriptive geometry.

The angle for the twisting rules was measured from the elevation, as well as the arch squares, and the soffit patterns from the development.

JAPANESE LACQUER WARE.

From "Journal of the Society of Arts."

THE export of lacquer ware, though not attaining to any very high figures, is a somewhat prominent feature in the productions of Japan. Mr. Robertson, the Consul at Kanagawa, states that the lacquer ware that finds a sale in foreign markets is, as a rule, that description into which a preparation of gold powder enters, and known to Japanese as "makiyé"; but, as many articles of daily household use in Japan are of plain lacquered ware, that is, without ornament, the material of wood with a coating of plain lacquer or varnish, the industry, whether looked at as affecting the export trade, or regarded as a permanent industry in the country, and one giving employment to many hands, can not fail to commend itself to those interested in Japan and its productions.

The groundwork of lacquer consists in the sap of the "urushi" tree, the fruit of which produces the vegetable wax. The Japanese distinguish between the male and female tree, the former bearing no fruit. The trees attain to a height of from 36 to 42 feet. In those parts of the country where the trade in lacquer is of any importance, the varnish is taken from the tree when it has attained to an age of from four to eight years. On attaining the latter full age the tree is cut down. Where the tree is cultivated for the sake of the wax, the sap is not extracted; and in Aidgu and Yonegawa, where the trees are specially reserved for wax, they will be seen to attain to no inconsiderable height. The "urushi"—lacquer varnish tree—is cultivated in two ways; either by sowing or by cuttings. In following the former, the front of the tree is lightly pounded in a mortar, so as to remove the rind from the seed. These are then mixed with wood ashes, moistened with water, and afterwards put into straw bags, over which liquid manure is poured, other bags are then left to soak in water until the close of the winter. Just before the commencement of spring, on a day duly noted on the Japanese farmer's almanac, the seed is sown broadcast over the ground, and slightly covered with earth. In respect to slips or cuttings, they are

planted out in rows, and thinned as soon as a leaf or two appears. Sowings, are, however, preferred, as it is found very difficult to rear from cuttings.

The amount of varnish obtainable from any one tree depends on the vigor of the tree and the quality of the soil. A good vigorous "urushi" will, after four or five years growth, have a stem of about six inches in diameter. The sap is generally drawn off on the tree attaining its fifth or sixth year of growth, and this is done in the following manner :—A lateral incision is made with a knife in the trunk of the tree, and four days later the incision so made is punctured. The sap that exudes is then carefully removed with a small spatula, and put into a wooden jar. One incision is made at a time, commencing from the root upwards, and the trees are taken in turn. This is continued until each tree exhibits a series of cuts all up the trunk. The tree is afterwards felled. The drawing off of the sap is begun in the middle of the summer and continues to about the month of November. The very first and last sap drawn is not considered of good quality. The best is that which is drawn off late in the summer. From spring to summer the sap ascends the tree, and afterwards descends. The expert is therefore guided by this fact as to where the incisions should be made. When the sap is descending in the trunk it is considered inferior. The bark of the larger trees being somewhat thick, the ordinary instrument in use sometimes fails to make proper incision, in which case the bark is first removed prior to making the incision. The "yamo urushi," on wild varnish, grows plentifully, and in leaf and flower resembles closely the "urushi," but it meets with little attention, as its yield of sap is very small. There is also a species known as the "tsuta urushi," or ivy lacquer tree, which attaches itself to trees after the fashion of ivy, but yields even less sap than the lacquer tree. Lacquer is obtained largely in the eastern portion of the empire, but to no great extent in the western provinces. The wood of the "urushi" tree being exceptionally good, is applied to many uses, and notably to the making of floats for fishing-nets.

Having thus given a brief description of the manner in which the lacquer varnish is obtained, Consul Robertson furnishes a few additional remarks upon the preparation of the lacquer ware. The Japanese, it seems, give the year A. D. 724 as the date when the art of lacquering was first discovered, but those amongst Japanese who have given attention to the subject fix the date at the year A. D. 889 or 900. It would appear to have attained to some perfection in the year 1290, for the name of a distinguished painter in lacquer who lived at that time is still handed down as the founder of a particular school of art in lacquer painting. From that time it developed until it attained its present perfection. The following is a brief general description of the mode in which designs in lacquer are worked :—The first thing is to trace out on the thinnest of paper the required pattern or design, and the tracing is then gone over with a composition of lacquer varnish and vermilion, afterwards laid on whatever it is proposed to impart the design to, such as the facing of a cabinet, or other piece of work, and well rubbed over with a bamboo spatula. On the removal of the paper the material below will be seen to have received the outline. This is now gone over with a particular kind of soft lacquer varnish. When this industry is pursued in hot weather the varnish speedily dries, and consequently, where the pattern is a good deal involved, such as one representing bunches of flowers or flocks of birds, a small portion only of the pattern is executed at one time, and the gold powder, which enters largely into most of the lacquer ware for the foreign market, is applied to each part as it is being executed. For this a large and very soft brush is used, and by its aid the gold powder is well rubbed in with the lacquer or varnish. The work is then left to dry for the space of about twenty-four hours, after which the pattern is lightly rubbed over with charcoal made from a particular wood, this process securing evenness of surface. The work is then rubbed with polishing powder, and afterwards carefully wiped.

There still remains a good deal of finishing work, such as the tracing of leaves on trees, the petals of flowers, the wings of birds, and so on, according to the particular subject in hand. Into all of these gold powder largely

enters, the working in which requires a light brush and skillful hand, so as to preserve an even mixture of the powder and varnish. After this has well dried, a particular kind of lacquer varnish, known as "yoshino urushi," is well rubbed in, and the whole then polished with horn dust. The polishing process is done with the finger, and is continued until the gold glitter shows out well. A beautiful polish is said to be thus obtained. Briefly, then, the designing on lacquer ware is done thus: supposing the subject is to be a flower, it is traced out on the paper and imparted to the groundwork of wood. Gold powder is then sprinkled over the work from out of a bamboo tube, well rubbed in with a brush, and then allowed to dry, afterwards polished, and a coating of varnish applied.

This is repeated several times, until the work assumes a rust color. The veins or tracery of the leaves are marked out with lacquer varnish. Before this dries gold powder is again sprinkled over, and then rubbed in with a brush. When the surface has dried, it is rubbed over with a piece of charcoal, so as to tone down any irregularities. After that it is polished, when the flower will appear in due form.

COFFER DAMS IN THE CONNECTICUT RIVER.

By W. H. BURRALL, C. E.

Written for VAN NOSTRAND'S ENGINEERING MAGAZINE.

In the summers of 1870 and 1871, the firm of Hawkins & Burrall, of Springfield, Mass., built five coffer dams in the Connecticut River at that place. As there were some features believed to be new, in regard to the thickness of dams, and details of the work, a plain account of their construction and operation, may not be without value, as a record of actual experience.

The bridge of the Boston & Albany Railway over the Connecticut River, was at that time a wooden Howe truss, single track, in seven spans of about 180 feet each. The six piers were of dressed Monson Granite on a foundation of piles, driven about 3 feet apart, capped, leveled up with concrete and planked. These foundations were put in about 1838, three of them by dredging out the bottom, driving the piles and sawing off near the bottom, which was then leveled with concrete and the masonry built in a caisson and sunk. The remaining three were put in by means of coffer dams, as to the details of which no information is at present accessible to the writer. Around the piers, loose stone or rip rap had been deposited, extending out some 18 or 20 feet from the piers, all around.

The bottom was composed of sand and gravel of varying degrees of hardness, among which were strata of quicksand, horizontal or nearly so.

The depth of water varied with the location of the piers, and the different stages of the river while the work was in progress from 3 or 4 to about 18 feet. The current was slight at that stage of water, not sufficient to form any obstacle to the work. The bottom of the bridge was about 28 feet above low water mark.

It was desired to replace the bridge by a double track, iron structure, and to do this, the piers were to be lengthened 20 feet on the south or down stream side. To secure a good bond of the new and old masonry, the ends of the piers were to be taken down, entirely to the foundation. A new foundation similar to the original one and in continuation of it was to be put in, which required removal of the rip rap at that end and some excavation.

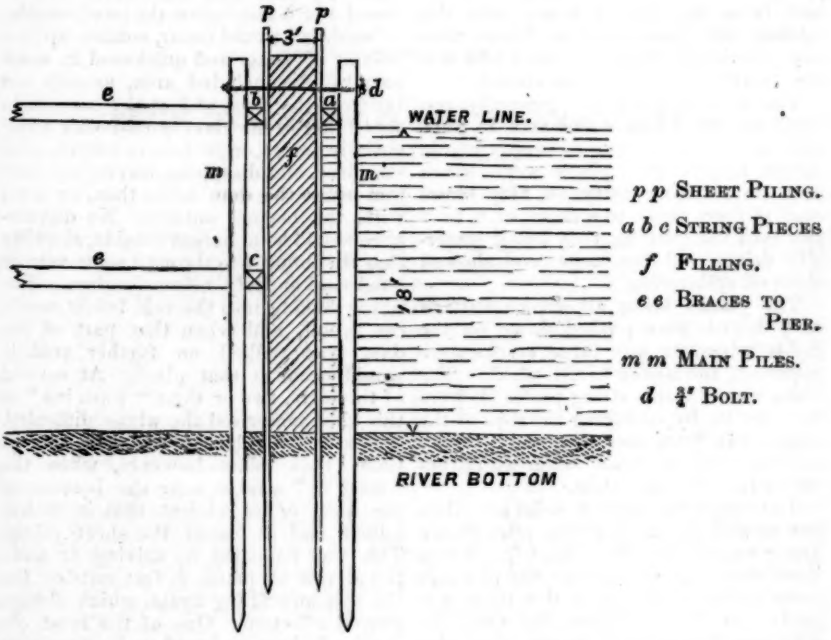
These conditions precluded the method of sinking the masonry in a caisson or by screws, which would be the natural course for a new foundation, and rendered the removal of the water necessary.

Though the bottom was one of the most unfavorable kind, it was believed

that a coffer dam of sheet piling furnished the most available mode of construction. The main danger seemed to be (as really proved the case) the veins of quicksand passing under the dam at all depths, and as no thickness of dam would obviate this danger, it was determined to build a much thinner dam than any authority could be found for, trusting to that merely to prevent *through* leakage, and dealing with the other difficulty as might seem best at the time, by dumping earth or sand bags outside, or additional sheet piling.

Another consideration was the difficulty and expense of procuring material for filling, which had to be brought on the railroad and dumped from the bridge above. The resistance to outside pressure was to be obtained by struts from the pier to inside of dam. It was decided then to drive two rows of 4-inch spruce plank, three feet apart, supported by outside piles and horizontal string pieces, on both sides, at intervals of about eight feet.

The plant for driving was as follows: A scow was built 18 feet wide, 50 feet long, and 2 feet deep inside. The sides and a parallel middle rib were made up



of two pieces Southern pine, 6″×12″, bolted together edgewise, and the whole cross planked with 3-inch spruce plank. It was entirely decked over and caulked and pitched so as to be water-tight. On the stem was placed the portable engine with drum and winch heads, and on the front end two pairs of gins, projecting slightly over the end, and three feet apart centre to centre. One hammer or monkey weighing 140 lbs. was used for driving the main piles, and for the planking, two were cast with a hollow centre, into which was driven a piece of seasoned white oak, to strike the plank. These weighed about 800 lbs. complete.

The manner of driving was as follows: The plank was sharpened on two sides, and the outer edge, had a pair of cast iron lugs, about 4 inches square, bolted on near the edge to project over and embrace the plank last driven. These were about 6 feet from the top and kept that in line.

It was then hoisted into the gins and the bottom entered between a pair of movable jaws at the foot of the gin, which reached by and embraced the plank last driven. Two planks being thus entered, the screw and plank were forced against the dam by lines from the dam to windlasses on the scow and successively driven to place. Once in ten feet the main piles were driven outside the plank.

In this way the dam was completed till the stem of the scow came in contact with the part completed. The scow was then turned at right angles to the dam, and by means of the projection of the gins from the scow and the hammer from the gins, a plank held flat against the gins could be driven, thus first the inner, then the outer row was put in, till the opening was closed.

The working gang was generally, one foreman, one engineer, one man in gins, two to tend lines, two to supply plank. About fifty to sixty plank were driven in a day, taking forty to fifty blows each to force them to a depth of 6 to 9 feet into the bottom, they being generally driven till the upper end showed signs of splintering.

The planks being all driven, battens of $\frac{1}{2}''$ boards were pushed down on the inside wherever any large cracks were apparent, and nailed to the plank. The lower row of inside string pieces (*b*) were then put in, by springing the tops of the piles away from the dam, and pushing the string pieces down under water, between the piles and dam.

The upper rows on both sides were then put on and the tops of the piles drawn firmly together by the bolts (*d*). Struts were then put in between the pier and inner string pieces, and the dam was ready for filling. When the water inside was low enough, struts were also placed against the lower row of string pieces.

Less than a mile east of the bridge, the R. R. Co. were lengthening a side track through a cut some 10 feet deep. This was found to be composed of strata a few inches thick, of a tenacious clay, and nearly pure sand alternately, in about equal quantities and was at once adopted for filling. Shutes or troughs were placed from the bottom of the bridge to the dam, and the material dumped from gravel cars on the bridge, and distributed by shoveling. The dam being filled, pumping was commenced. A boiler and reciprocating steam pump placed on the dam was used at first, but much trouble was experienced from choking of the valves by sand, etc. Later a horizontal centrifugal pump was placed in the dam at the bottom, which gave perfect satisfaction, raising a 7 inch stream, 20 feet, and discharging sand, stones &c. with perfect freedom.

Meanwhile the scow and gang were driving the next dam.

Not to enter into too much detail, the general experience in pumping out was this. By the time the water was reduced 5 or 6 feet below the level outside, a "wash in" would occur, coming up in a volume of water and quicksand in some part of the included area, usually not far from the dam, and at the same time the filling in the dam would sink away entirely for 15 or 20 feet in length, over the place, and disappear, leaving the bottom inside the dam lower than, or level with, the bottom outside. No disturbance would be apparent outside, showing that the influx was through some vein of quicksand entirely below the dam. The filling sinking into the vein below would cut it off, and when that part of the dam was refilled no further trouble would occur at that place. At several of the piers, two or three "wash ins" of this kind comprised the whole difficulty.

A more troublesome variation several times took place however, when the "wash in" was so near the bottom of the dam, or so violent that it undermined and displaced the sheet piling. This was remedied by driving an additional row of plank, 3 feet outside the old ones and filling again, which always proved effectual. One of the most obstinate leaks was found to be produced by a bar of railroad iron lying transversely under the dam in the river bottom. In one case the break took place just opposite the pump which was covered some feet with quicksand. By raising it, (the centrifugal pump) on top of the sand and gradually lowering, sand and all was pumped out.

When the bottom was exposed, water would be found coming up in various places, over the enclosed area, but in no case greater than could be exposed by

the pump. The excavation for foundation was then easily made, piles driven, the new foundation completed and masonry laid.

After the masonry was above water, the planks were pulled up, and most used a second, and many a third time. The pulling up was effected by slinging a heavy four-fold tackle to the gins, and leading the fall to the engine. The first pull would generally bring the end of the scow some inches under water, but by holding on a few moments the plank would let go and come.

It would seem then, from this experience, that when a coffer dam can be braced from the inside, which may generally be done, a much less thickness may be employed than is usually recommended. This, however, depends greatly on the character of the material used for filling, and four feet would probably be preferable to three, though little or no trouble was experienced in this case from any leakage through the dam itself. The employment of cast lugs, easily applied and removed, was a very satisfactory substitute for tongueing and grooving, and the double pile driver and method of driving arose naturally from the character of the work, and seemed to meet every requirement.

THE MANUFACTURE OF CAOUTCHOUC—AND ITS INDUSTRIAL USES.

By EUGENE PAVOUX.

From the "Universal Review of Mining."

The multifarious uses of india-rubber, and the numerous industries in which it is employed, are such as to give an interest to the consideration of the properties of this material and of the means employed to give it the appearance and the forms under which it is rendered useful.

Its principal quality is its elasticity in an ordinary temperature. This special quality, to which it owes its repute, disappears almost entirely under a temperature approaching to that of melting ice, and only re-appears when the india-rubber is subjected to a heat of from 30° to 40°, when it again becomes supple. It softens in proportion as the temperature rises, becomes viscous, and ends by taking the consistency of treacle. This sensibility to the influence of the temperature must have prevented its being used in industrial pursuits, if means had not been found of neutralizing it by a special manufacturing operation. Above 200° it is decomposed, and passes off in a volatile form.

Its density varies between 0.925 and 0.950.

According to Faraday, it is composed of 87.2 of carbon and 12.8 of hydrogen.

India rubber is a sap which flows from various sorts of trees which grow in abundance in the regions near to the equator, notably the *Ficus elastica*, the *Siphonia Cahucha*, &c. Its qualities are distinguished by the places where it is grown, and sometimes, though rarely, by some external characteristic. The terms most frequently used in the manufacture are: Para, Madagascar, Carthagena, Guyaquil, Borneo, West India, Assam, &c.

It is obtained as follows:

The trunk of the tree is pierced, and the sap (which contains about 40 per cent. of india rubber) is allowed to run off into a vessel, but more frequently into a hole dug at the foot of the tree. Balls of dried clay are made in the shape of pears, which are plunged into the liquid, and afterwards made to pass over a fire made of the branches of trees, in order that the layer of india rubber which has been deposited on the clay may be made to coagulate rapidly. This operation is repeated until a certain thickness has been acquired. The pears are then plunged into water, and the clay, thus softened, is easily got rid of by simple pressure.

Sometimes a thin board is used as a nucleus, on which the sap is deposited

and agglomerated; in this case, the mass of india rubber thus collected is cut on three sides to admit of the board being drawn out, and in this way double sheets are obtained, which open almost in the same way as a book. The purest india rubbers are those which are gathered in this way; such are Para and Madagascar, the simple aspect of which reveals the almost total absence of extraneous matter.

When the sap is allowed to run out on the ground, it collects in irregular strips, mixing with the impurities of the soil. These strips are put into sacks and sent off to the various places of consumption. When they are very thin they are rolled up like a skein of thread, and the appearance of the india rubber in balls serves to remind one of a clue of worsted.

In these different states india rubber arrives in Europe. It is indispensable to rid it of every kind of detritus, sand, wood, pebbles, bark, &c., which have become mixed with the gum whilst running from the tree. This is the object of the first process in the manufacture. The raw material, after being softened by immersion in a large tub of hot water, is cut up with a saw into cubic pieces of about an inch and a-half, then flattened between two cylinders, horizontally placed, the distance between which is regulated at will by attachment screws. These cylinders are of different velocities; it follows, therefore, that, independent of the pressure which the india rubber is made to undergo, it is hacked and torn to such an extent that all extraneous matters are removed, and, under the continuous action of a stream of water, are easily carried off. Under this process, which is repeated eight or ten times, and every time bringing the two cylinders nearer together, all the impurities vanish, and it assumes the form of an irregular sheet, grained, and pierced through with innumerable holes. This sheet, when hung up to dry in a place where the air circulates freely, thanks to its texture, very soon loses the water with which it is impregnated.

It is important that the material should be kneaded, in order to bring together in a single piece the scattered elements of the sheet, and impart to it perfect homogeneity. This is done by means of a kneader called a *devil*, which consists of a cylinder fixed horizontally, divided or not into separate compartments by partitions perpendicular to the axis. Over the total length of this cylinder, and a quarter of its circumference, there is an opening by a sort of door on hinges, through which the dried rubber is introduced. A shaft, provided with a series of sharp pointed teeth and disposed in rows alternating one with another, runs through the whole length of it. This shaft, which makes seven or eight revolutions a minute carries along with it the grained sheet of which we have spoken, and causes it to traverse the entire free space of the cylinder. In doing this the mass of caoutchouc takes a rotating motion, produced by the teeth, which successively take it up and draw it towards them. There results from this a perfect process of trituration, which forms the sheet of rubber into a compact mass, all the parts of which are thoroughly mixed.

In order that this operation may be effected under proper conditions, it is necessary that the roll of caoutchouc which has to be put into the cylinder should be a little wider than the cylinder itself, in order that it may press against the sides, and, consequently, be regularly drawn in by the motion of the shaft. This proceeding lasts, on an average, a couple of hours; the longer it is continued, the less time is required for the process which has to follow, by reason of the thorough homogeneity into which the material has been brought.

The *devil*, as it is called, is usually formed of a double casing, which is heated by means of a steam jet. I have been induced to abolish this, because I find that the heat developed by the work itself is sufficient to facilitate the kneading of the material, whilst if it is increased by that arising from the steam, the temperature is such as to cause the rubber to become soft and viscous, which deteriorates its quality and interferes with the following operation.

On leaving the *devil*, the material passes to the compressing cylinders, which are placed in couples on a horizontal plane, and may be brought to any distance from each other by means of attachment screws worked by a crank placed within the reach of the workman.

These cylinders are hollow, and are

heated internally with steam by a pipe running through a padded box. Two pipes running into one serve to discharge the steam, the ingress and egress of which are regulated, according to the necessities of the work, by taps. The rubber is thus thoroughly compressed until it presents the aspect of a rolled-up sheet, of firm texture, close and exceedingly smooth. This gives the finish to the preceding operations.

India rubber is only used for certain special purposes. The requirements of industry demand various qualities of products, possessing properties suitable to the different uses to which they have to be applied; it is the mixture of blocks of compressed rubber with foreign matters in certain proportions which enables the manufacturer to produce qualities answering to the variable conditions under which they have to be used. Rolling forms a mixture of these several substances, which is regular and uniform throughout; it is also during this operation that the coloring matter is added, which gives to india rubber its various shades of gray, black, red, &c., in which it so frequently appears. It is in the form of powder that all these matters are mixed with it. At every passage between the cylinders a portion of it escapes, and falls on a slightly inclined table, which is gathered up by the workman and thrown again into the mass, which, becoming wider by the pressure, is rolled up by the workman as it issues from the cylinders, between which he puts it in afterwards lengthwise. It is, therefore, rolled in every possible way, which tends to give to the texture a greater degree of homogeneity.

The india rubber paste obtained by this process is afterwards worked up either by rolling or moulding.

In the first case sheets are made of any length and thickness that may be required, whilst in the second, it is cast in any mould the manufacturer may desire.

As regards the rolling, the paste is made to pass between the two cylinders of a calender, by which it is spread out into a sheet of the same dimensions as the cylinders; these sheets may be made to any length, of course, by feeding the calender continually with one block of material after the other. The adhesive tendency of india rubber is so strong that when the finished sheet has to be wound on to a roller, it can only be done by the interposition of a piece of cloth, which serves to separate the different windings of the sheet. It is then placed on a table and unrolled, in order to be worked up into the form and dimensions required. The same calender serves for coating cloth, which is used for so many purposes, amongst others, for making tubes and straps; the paste, which passes through the cylinders at the same time as the cloth, is spread upon it in a layer, the thickness of which is regulated by the distance, and the tenacity with which it sticks is in proportion to its adhesive qualities.

Certain pieces are suitable for special forms, which they can only be made to take by moulding. In order to manufacture these the india-rubber paste is put into a mould, which is filled more or less correctly. The exposure of this mould to a temperature varying between 125° and 150° causes the material to expand and penetrate into every part of the mould, and to take the exact form that is wanted. If a hollow article is required, a little water is introduced, which, in being changed into vapor by the heat, compresses the paste, and makes it adhere to the sides of the mould, of which it takes the exact outline.

There is one remark which it is important to make: it is that the paste adheres easily by simple contact, as long as the material has not undergone the process of *vulcanization*. The shape then (with exception of the cutting up of certain objects into sheets) should always be given previous to vulcanizing, which is the last process of manufacture.

Raw india rubber seems to consist of two parts, each possessing distinct properties: the one compact and elastic, the other heavy and semi-liquid. It is to the presence of the latter element that is to be attributed the extreme facility of adhesion by which it is characterized, and it serves to explain the way it is affected by the action of cold, and the modification it undergoes under the influence of a high temperature. The transformation of the viscous part, so sensitive to the variations of heat, must have the effect of preventing those grave inconveniences arising out of it, and of making india rubber a sub-

stance that can be utilized under any conceivable circumstances. That is the object attained by *vulcanization.*

The agent employed for vulcanizing is sulphur. Its action on india rubber is analogous to that with which it acts on fatty substances which, when mixed with it in the proportion of one to five, and heated by a temperature of about 200°, produces a substance which offers a good deal of resistance, and which presents almost the aspect of india rubber. The result is that vulcanized rubber does not harden with the cold, neither does it soften with heat; it preserves its elasticity, resists acids, and can no longer be made either to dissolve or to stick.

The incorporation of sulphur is effected either in the solid state or in a state of fusion, according to the nature of the articles that have to be vulcanized. The first method, which is the most in use, consists in mixing flowers of sulphur with the rubber at the same time as the other matters which are added in rolling; it thus becomes uniformly mixed with the mass, but as the re-action to which it must give rise can only be produced at a high temperature, it does not so far modify the properties of the india rubber paste, which still continues to stick. The article which is being made is put into a boiler, made of sheet iron, capable of supporting a pressure equal to from four to five atmospheres, and closed by a bolted lid; a jet of steam is let in, the tension being measured by a steam gauge, and the length of time during which the operation continues varies according to the number of pieces, but it is estimated at a couple of hours on an average. The necessary temperature is about 150°. When it is required to put several objects one on the top of the other, they are sprinkled all over with silicate of magnesia to prevent them from adhering to their supports.

The articles manufactured in moulds with an open surface are vulcanized in presses composed of two hollow, horizontal planes, the uppermost of which is movable, and worked by screws which allows it to work up and down. The moulds are placed between these two planes, and in this manner the paste is compressed. The necessary temperature is produced by the steam which circulates in them, and which has been brought there by pipes placed at one of the extremities, and which rises to the other end through outlet pipes.

I have had fixed in my manufactory a large press of this kind, by which I am enabled to vulcanize sheets, with great economy of time; the planes are about 7 feet long by 4 feet wide, their internal surface being carefully planed and dressed gives to the sheets a glossy appearance, with remarkable uniformity of thickness.

To produce vulcanization by the liquid method, the sulphur is put, in a state of fusion, into large boilers, underneath which are large fire-places; the articles already made are plunged into these boilers, care being taken to keep them covered with the liquid by means of weights. This precaution is indispensable, in consequence of the difference in density of the sulphur and the rubber. The absorption of the metalloid takes place, and is gradually completed until the combination is effected, which takes from two to three hours. Experience will be the best guide as to the time when the operation has been accomplished. Care must be taken that it is not continued too long, because in this case the rubber becomes hard and loses its elasticity. As soon as the articles are taken from the boiler, they should be plunged into cold water; this causes the layer of sulphur deposited on the surface to crack, after which it is easily removed by simply scraping it.

It is as well to remark that only small objects admit of this method of vulcanization; those of larger volume must undergo the first process.

There are also other methods of vulcanization which, although less applicable to industrial products, nevertheless deserve to be mentioned. Chloride of sulphur mixed with sulphuret of carbon, in the proportion of one to fifty, will produce this result. When immersed in this compound, the rubber becomes impregnated in a few minutes, after which it is plunged into a reservoir of cold water: the object of this is to neutralize the effect which a too prolonged immersion would have upon the surface, which would be to vulcanize it too much. During the immersion, the mixture penetrates into the centre of the mass. It is only ar-

ticles that are not very thick that can be subjected to this process.

It is exactly the same as regards the process which consists in the use of alkaline sulphurets; the operation lasts about four hours. In consequence of the restricted application of this method, it may be regarded as more theoretical than practical.

After vulcanization, the surface of the rubber sometimes presents slight efflorescences of sulphur; these are easily removed by washing with an alkaline solution.

To dissolve india rubber, no better agent can be employed than sulphuret of carbon, to which must be added 5 per cent. of anhydrous alcohol; a product is thus formed which, when subjected to evaporation, leaves a residuum of rubber possessing all its primitive qualities. It may also be dissolved by any of the essential oils, but the material which results from their evaporation is oily and viscous, so that their use has been entirely adandoned.

Before proceeding to treat of the industrial uses of india rubber, it will be interesting to say a few words respecting indurated rubber, which constitutes a special branch of manufacture independent of its restricted application to great industrial purposes, it is applied to the manufacture of a large number of objects of all shapes and dimensions, adapted to ordinary daily wants. The manufacture of indurated rubber may be disposed of in two words. The quantity of sulphur which is mixed with the paste is larger, and amounts, according to circumstances, to from 35 to 40 per cent., and the vulcanization is prolonged beyond the ordinary limits, the maximum being from six to seven hours. For great thicknesses, a longer time may be necessary, but this is an exception. The operation is a very delicate one and demands a great deal of care to prevent the article being burnt, which, in that case, would become worthless.

Indurated india rubber is worked with the file, the saw, and the lathe, exactly like metals and other hard substances.

The applications of india rubber to industrial purposes are exceedingly numerous, and are increasing daily. "Its elasticity, its tenacity, added to which, the property it possesses of being completely homogeneous and impermeable, recommend it for a vast number of uses in which it would be difficult to find a substitute." (*)

The various kinds of joints which are used for water pipes, gas pipes, and steam pipes, may be classed in several categories, and are all practicable with india rubber. The flat washers for flange joints are made in various qualities of material, but most frequently by means of one on several cloths dipped in the paste, and intended to prevent the lateral extension which would take place in pressing the surfaces together, as well as by the heat, in the case of joints with steam at high pressure; the number of cloths depends upon the thickness of the washer. Instead of being parallel at the surface, the cloths are frequently disposed concentrically, and are placed at a distance from each other of from 2 to 3 millimetres. The same result may be obtained with felted india rubber, that is to say, mixed with fibrous matter, such as woolen or cotton waste, &c., which, by their resistance admit of greater tenacity, and cause the lateral extension to be less felt.

In laying the flange pipes, it often happens that, through the negligence of the workman, the centre of the washer does not coincide with the axis of the pipe, and causes a projection in the inside. When this defect presents itself at the lower part of a steam pipe it prevents the waste water from running off; it is better, therefore, to adopt the system where the washer is kept in its place by a flange at one of the ends of the pipe; the play left between the two pipes admits of expansion, without causing any danger.

The washers with circular section which are used for joining the pipes, are especially employed in the ingenious system of which M. Leon Somzé is the inventor. The washer is introduced by being rolled into the annular space between the two ends, called male and female, of the jointing pipes, and is kept by the conical form of the male end in a perfect state of compression.

India rubber is also largely employed in transport. On the railways, the buffers are furnished with a series of wash-

* A. Stevart: "Results of Experiments in the Elasticity of Vulcanized India Rubber."

ers of rectangular shape about 2 inches in thickness, separated from each other by sheet iron plates, which allow each washer to be compressed singly, so that every advantage is derived from the characteristic property of the material. To allow the passage of the buffer rod, these washers are pierced into the centre with a hole, the diameter of which is larger than that of the plates, in order that the depression of the washer may not drive back the rubber against the rod. For the same reason, the sheet iron plates are of larger diameter to prevent the rubber from being pressed back beyond their outer edge.

In the construction of passenger carriages, arched pieces are used, which, being fixed in the inside of the wainscoating of the doors, receive the shock of the glass windows as they are lowered, and preserve them from the breakage to which they would be exposed without this precaution.

In the tramways, the springs are replaced by buffers, taking the form of two truncated cones, united by their great base; these buffers, placed between the box and the axles, weaken, by their elasticity, the jolting of the cars, and render the motion excessively smooth and gentle. The tenacity, strength and duration of the springs depend on the proportion of foreign matter which the material contains; there ought to be only a small proportion, but a certain quantity is essential, in order to give them the requisite body and solidity. The use of these springs in the wagonettes belonging to mines and quarries would, undoubtedly, diminish the deterioration in the rolling stock by preventing the violent shocks which are frequently caused by the dilapidation of the roads.

India rubber is also used for the outer rim of wheels for vehicles used in railway stations, large manufactories entrepots, &c. In this case, the metallic rim of the wheel takes the shape of a groove, in which the elastic band is embedded; the diameter of the latter is ordinarily calculated at four-fifths of that of the wheel.

Road locomotives appears to have acquired an increase of tractive power by the application of similar bandages. There is no vehicle, even down to the velocipede, which does not make use of this material, endowed as it is with so many precious qualities.

It enters largely into the construction of machines, and especially of pumps. The clappers vary in form as well as in thickness; some are round, others are square or rectangular.

The seat on which they rest has several apertures, they are thus supported otherwise than on their edges, which preserves them against the pressure. The metallic breastwork which forms the seat ought to present no projecting edge, which would enter into the material, and cause speedy deterioration. These clappers are, for the most part, made of simple india rubber, but sometimes cloth is put between to give them greater tenacity. The special circumstances under which they have to be employed will guide the maker in the selection.

Certain valves are composed of a simple metallic sphere, covered with india rubber, which, being raised by the liquid, falls down again as the piston descends, on the orifice it is intended to close. In order that these valves may retain sufficient suppleness to admit of their hermetically closing the orifice, it is better that they should consist of a hollow india-rubber sphere, filled almost entirely with small shot.

An ingenious application of india rubber is that which has been made by M. Field, in respect to a valve composed of two india-rubber discs slightly conical, and placed face to face. These discs are flat and pierced with a hole in the centre, but they are compressed, and made to assume a conical shape by the metallic pieces which retain them, in the interior. Their external edges are in contact with each other, and maintained thus by the pressure which is exercised on their outer faces. The principal merit of these valves is their perfect resistance to the strongest pressure; in fact, their action being exerted in every part at the same time, the lips of the valve are forced against each other, with an energy which is greatest when the pressure is strongest. Messrs. Whitley Partners, of Leeds, have applied this valve to all kinds of pumps, for pumping either cold or warm water or other liquids at pressures rising as high as ten and even thirteen atmospheres.

As regards pumps which are intended to pump acids, an india rubber bucket is used, in which the rod of the piston is placed; these pieces are moulded.

Hydraulic press rings made of india rubber, replace advantageously those covered with leather, which are high in price. These rings are moulded in exactly the form required, and they are much more flexible than leather ones, even of the very best quality.

India rubber is well adapted for the clappers of blasting machines. The firm of Cockerill, at Seraing, use it for that purpose in their works for the manufacture of Bessemer steel. These clappers, which have to do an enormous quantity of work, last from three to four weeks, notwithstanding the eminently unfavorable conditions under which they work, and the immense wear and tear to which they are subject.

India rubber pipes, by reason of the multiplicity of their uses, and the diversity of their composition, form an important branch of manufacture. Those that are used for gas, acids, &c., and have to bear only a feeble pressure, are made of pure rubber by simply rolling a strip of paste round a mandrel; the soldering is easily effected by contact merely, and is consolidated by the pressure of two small blades, worked by hand. To prevent the paste from adhering to the mandrel, care is taken to do it over first with powdered talc. Sometimes several strips are placed one on the top of the other, the number being determined by the thickness of the pipe which is being made.

When the tubes are intended to be subjected to a certain pressure, they are consolidated by the insertion of one or more layers of cloth, the cohesion of which prevents the swelling of the pipe, the wearing away of the sides, or their rupture under extraordinary pressure. These pipes are generally formed as follows :—A round of india rubber on the mandrel forms the first tube, over which a strip of cloth is rolled, done over with india rubber by a calender; a fresh round of pure paste is followed by a second covering of cloth, and the operation is repeated according to the number of folds the pipe is intended to have : this number of folds depends on the diameter, and increases generally with it. The outer envelope is in india rubber, so that the pipes represent rounds of cloth completely steeped in paste. By increasing the number of rounds of cloth, we obtain pipes capable of resisting the strongest pressure.

When a liquid has to be inhaled, it is necessary to guard against the crushing of the pipe, which the atmospheric pressure, added to the internal vacuum, would inevitably cause. For this purpose a spiral is used, made either of galvanic iron or copper, which is either simply placed in the interior of the tube, or is embedded in the thick part of the rubber. Generally, the outer part of the tube is formed of coarse cloth, which serves as a protecting envelope, as these pipes are nearly always intended to be trailed on the ground; they are much used for fire engines and pumping engines.

All these kinds of tubes can only be vulcanized after they have been finished. They are put into a vehicle which runs on rails, and put into a boiler 20 yards long, specially prepared for them.

A particular kind of pipe is made of tanned hemp, with an inside casing of india rubber, and can be advantageously applied to a great number of uses. Being tanned, it is enabled to resist moisture, which has not the slightest effect upon it. It is much lighter than leather, consequently, in case of fire, a man can carry a much greater length, and can mount a ladder with it much more easily. The application of india-rubber sheets to the interior of these tubes prevents the infiltration of water into the pores of the tissue; it also prevents any loss of liquid, and protects them from injury. The resistance is very considerable; a diameter of $1\frac{1}{4}$ in. will bear a pressure of fifteen atmospheres, and one of $\frac{3}{4}$ in. will bear twice the amount of pressure. They are used for fire engines, for brewery funnels, water pipes, steam pipes, &c.

The ropes used for wadding, which are made of cloth, done over with india rubber are made without core, that is to say without any inner nucleus in pure rubber; they are generally used concurrently with hemp for furnishing stuffing boxes, and with the best results; the flexibility of the hemp admits of the expansion of the rubber, and this, in its

turn, corrects the want of compactness presented by textile fabrics.

Straps merit special notice. They are composed of a certain number of folds of cloth done over with rubber, alternating with layers of pure rubber. The number of folds, and, consequently, the thickness of the strap, is in proportion to its width: for this reason, when the width is above 10 centimetres, there are at least three folds; above 15 centimetres, four folds; and above 25 centimetres they have from five to seven folds. They are made of all lengths in a single piece, and are joined exactly like those in leather. They work as well in water as in places heated to a high temperature. Their use is becoming very general, for besides being less costly than those in leather, they adhere much better. It is important that the several cloths of which they are made should not slip one over the other, and that they should be made to adhere firmly by the intermediate layers of rubber. This object is attained by their being vulcanized in the press.

India rubber has been used for some time for covering metal rollers employed for sizing and finishing cloth; wooden rollers are replaced by metal ones, which prevents the necessity of using paper or cotton for stuffing the inside of the dressing cylinder; it also does away with the use of linen or woolen cloth for the external covering of the roller, one or more sheets of india rubber being now used instead. Manufacturers find great advantage in this. The size, whether colored or not, adheres sufficiently to the rubber to admit of either threads or tissues being well sized without any absorption of the material by the rubber; the size, therefore, as well as the coloring matter can be taken off the roller by simply washing it with water, which permits the immediate use of the same apparatus for sizing in other colors. The india-rubber covering, by adhering thoroughly to the metal, and having none of those protuberances caused by the crossing of linen or woolen covers presents a perfectly smooth and regular surface, and gives greater uniformity to the sizing. In short, the size not being in contact with the fire, in consequence of the impermeability of the rubber, there is no fear of any of those re-actions which might happen with certain coloring matter.

The thickness of the covering varies from 12 to 15 millimetres, according to the diameter of the cylinder. To have it in good order, one surface of the cylinder should be perfectly smooth.

Billiard makers secure great elasticity for their side slips by using india rubber, to which they give various shapes at discretion. The material used for this purpose ought to have rather greater density than the raw rubber.

The other industrial uses to which it is applied are innumerable, we need only mention the buckets and funnels used for acids, plugs with and without holes, rings and flanges for the joints of washing machines, rollers for twisting frames, sets of pulleys for ribbon saws, guide straps and aprons for paper-making machines, joints for filter presses used in sugar manufactories, moulds for hat manufacturers, aprons for sugar works, &c., &c.

As regards the application of indurated rubber, we may mention the rollers for spinning frames made in two parts of different composition and color, the vulcanization of which is effected gradually, by means of a slow and progressive elevation of temperature, and lasts about four hours.

In telegraphy, isolating bells are used, suspended on hooks of galvanized iron. The outer surface is polished all over, and presents a thickness of 2½ millimetres, so as to cut off the electric current.

If we were to point out all the applications of india rubber to surgery and ordinary uses, we should become involved in an endless nomenclature utterly at variance with the object of this brief memoir.

REPORTS OF ENGINEERING SOCIETIES.

SOCIETY OF ENGINEERS.—The first Ordinary Meeting of the Society of Engineers for the present year was held on Monday evening in the Society's Hall, Victoria Street, London. At the conclusion of the ordinary routine business, the retiring president, Mr. J. H. Adams, presented the premiums of books which had been awarded for papers read during the past year. Mr. Adams then retired from the chair, and introduced the president for 1876, Mr. Vaughan Pendred, who proceeded to deliver his inaugural address.

After commenting briefly on the satisfactory position of the society's affairs, Mr. Pendred went on to say that he had met with no small difficulty in finding a subject for his address which had not already been ably handled by his predecessors, and that the subject which he had finally selected was one which, if it presented no other merit, was at least comparatively novel. They had all heard a great deal, no doubt, of a subject very interesting to biologists, namely, Man's place in nature. He hoped they would give him a patient hearing while he said something concerning the engineer's place in nature. Mr. Pendred then proceeded to define what an engineer was, and went on to explain that the engineer's place in nature was that of the great civilizer. He pointed out that nearly all the natural comforts of modern life were due to the engineer, and he then pointed out that the engineer had great privileges and grave responsibilities. One of the privileges was that he alone could supply the soundest investments for the great mass of capital now lying idle to the great injury of trade in this country. He then expressed his opinion that engineers in Great Britain had during the last year or two manifested less energy than was desirable in supporting new engineering works, a circumstance originating, no doubt, in false delicacy, and certain to operate injuriously on the best interests of the nation. The privilege of the engineer was to find employment for money in developing the revenues of his and other nations, and so advancing civilization. The responsibilities of the engineer were defined by the fact that unless he exerted himself energetically, much suffering and disease and want of civilization must continue to exist. The engineer alone could improve the mutual economy of the world, and if the world was to be happier and better, the engineer, and the engineer alone, could produce that result. He might be asked what the engineer was to do, but he would not attempt to lay down principles of action which would suggest troubles to thoughtful members of the profession. He might point out, however, that a great necessity of the day was the improvement of the water supply of our towns and cities, and that this work required the best attention of the profession, which would find plenty of work in supplying the want. The regulation of our rivers, so as to prevent floods in winter, and to secure storage of water in summer was another great work. But the greatest of all was the cleansing of the country by an efficient method of dealing with sewage. After alluding to experiences in coal-pits and the construction of harbors of refuge as eminently claiming the attention of engineers, Mr. Pendred finished his address with a hope that when he resigned the chair to his successor, it might be found that if he had not merited the praise of the Society of Engineers, it would at least be found that he had not deserved their censure.

Royal Scottish Society of Arts.—A meeting of the above Society was held lately in Edinburgh, Mr. John Milne, President, occupied the chair. Dr. Walter Scott Carmichael read a paper entitled "A Description of the Patent Breakwater Steamer," invented and patented by himself three years ago. The ship consists of a nearly flat-bottomed hull, the sides below the water-level being nearly perpendicular, but several feet above the water-line these sides are continued with an inward slope, eventually becoming a roof over the main deck. At a distance of seven or eight feet above the main deck the sloping roofs end in a flat horizontal, partly glazed, to allow the more violent waves to pass harmlessly from windward to leeward. A spar deck above the horizontal roof affords facility for working and steering the vessel, the moving power of which is intended to be one or more propellers, working in tubes, which run from stem to stern of the ship. Dr. Carmichael expects that his breakwater steamer will advance straight-through the waves instead of rising over them, and hence greater steadiness will be secured than in the case of ordinary ships. Mr. D. C. Mudie, founder, in the course of the discussion which ensued, expressed the opinion that Dr. Carmichael's steamer was, as nearly as possible, like the shape of Noah's Ark, which for carrying power and stability was the best shape of vessel yet invented. The paper was remitted to a committee to report. Mr. T. B. McFadzen followed with a paper, communicated by Mr. C. J. Henderson, on a new system of heating churches and other buildings. The system, it seems, had been applied by Mr. McFadzen to a church in Grahamstown. A small chamber is erected at the end of the church with an opening from the building itself. In this chamber the stove is placed and the smoke pipe carried into and through a fire clay pipe, which is led up through the gable towards the roof, where the fire clay pipe opens into the church and the smoke pipe is continued to the roof. The heated air in the stove-room flows up the fire clay pipe to the ceiling of the church, a circulation being produced by the cold air rushing from the church into the stove-room. It is necessary that the whole of this process be accomplished before the congregation assemble, and the heat must then be diverted elsewhere or the fuel in the stove withdrawn. On the congregation leaving, the process is re-commenced, with the difference that fresh air from the outside is supplied to the stove, and the doors of the church are left open to allow the foul air in the building to escape. Dr. Stevenson Macadam pointed out that there was no provision for ventilation from the outer air during the time the people were in church, and that in a short time the vitiated air breathed by the congregation would be breathed over again. This view seemed to be concurred in by other members.

Institution of Civil Engineers.—The paper read was on the "Holyhead New Harbor," by Mr. H. Hayter. Between the years 1835 and 1847 the attention of Government had been directed to the importance of providing improved harbor accommodation on the coast of North Wales, to facilitate communication with Ireland, and when the bridging of the Menia Straits by the Chester and Holyhead

Railway Company became no longer a matter of doubt, Holyhead was selected as the most suitable place for the packet service, as well as for a harbor of refuge. Of the several schemes proposed, the plan suggested by the late Mr. Rendel, past-president Inst. C.E., was ultimately accepted, and was sanctioned by Parliament on the 22nd July, 1847. It comprised a north breakwater, 5360 ft. in length, and an east breakwater, about 2000 feet in length (inclosing an area of 267 acres of available water space), and a packet pier, 1500 feet long, within the area. The east breakwater and the packet pier were subsequently abandoned. But it was found, as the works advanced, that the harbor was likely to prove too small, even for refuge purposes. The Lords of the Admiralty therefore decided to lengthen the breakwater to 7860 feet from the shore, to shelter a roadstead of 400 acres of deep water. The north breakwater consisted of rubble stone with a substantial stone superstructure. To convey the stone, nearly 2½ miles of single line of railway were constructed, besides other preliminary works, the total cost of which had been £92,000. The rubble mound was of great size—the average depth of water at low-water spring tides being 40 feet, and the greatest depth 55 feet—the variation of the tide at ordinary spring tides being 17 feet, and at equinoctial spring tides 20 feet. At the level of low water the mound was nowhere of less width than 250 feet, and in 50-feet depth of water it was about 450 feet wide at the base. It contained altogether about 7,000,000 tons of stone. The rubble mound having been formed, and consolidated by the action of the sea, the superstructure of massive masonry was erected. This was principally of quartz rock from the quarries, the plinths, cornices, parapets, paving, copings, and other ashlar work, being of Anglesea limestone. The work was set in lias-lime mortar. The foundations were laid at the level of low water, for which purpose the loose stone of the mound had to be excavated. The wall was built near the inner edge of the stone deposit, to allow as long a foreshore on the sea as possible, and had been carried up to a height of 38 feet 9 inches above low water to the level of a promenade, which was surmounted on the sea side by a parapet. At 27 feet above high water there was on the harbor side of the breakwater a quay 40 feet wide. The head of the breakwater was 150 feet long and 50 feet wide, founded on the rubble mound at 20 feet below low water, and was for the most part of ashlar masonry. The cost of the north breakwater and works connected therewith, including land, had been about £1,285,000, and per lineal foot about £163 10s. The cost of the stone deposited in the rubble mound had been 2s. 3d. a ton for the first portion of the breakwater, and 2s. 7d. a ton for the last 2500 lineal feet. The cost of the superstructure alone, excluding the head, had been £36 a lineal foot.

IRON AND STEEL NOTES.

THE HIGH ANTIQUITY OF IRON AND STEEL—By ST. JOHN V. DAY.—With regard to Indian iron manufacture I have, in the first place, to correct an error I formerly made as to the date and place of the Iron Laht at Delhi. From all that I could then gather it seemed to belong to a period ranging from the first to the fourth century of the present era; but since that time Lieut. Cole's magnificent work on ancient Delhi, of the existence of which I was not then aware—indeed it does not appear to have been published at the time my paper, which especially referred to the Laht, was written—has come under my notice.

The iron column instead of being situated where I formerly stated is, I now find, in the axis of the colonade of the Masjid-i-Kutb-ul-Islam.

M. Garcin de Tassy has translated the Persian account of the column written by Syud Ahmed, and has supplemented it with some weighty remarks, from which it appears to have been set up by an otherwise unknown king, Rajah Dhava, *alias Midhava*, and whilst it now seems that the forging was made in the ninth century B.C., or from 1,100 to 1,200 years earlier than I had formerly stated, yet the inscription upon it is of much later date, M. de Tassy concluding the inscription to be possibly as late as the third or fourth century of the present era, and inscribed, therefore, by a king long subsequent to its originator, who, indeed, we learn from Indian history, died in the course of its construction. I have also to add that a cast of this remarkable column is now on view at the South Kensington Museum; also, that a piece of the metal has been cut from the pillar, and this piece has both been forged and analyzed by Dr. Percy, who has pronounced it as soft *wrought iron*.

Whilst speaking of India, I cannot, however, pass over that unique collection of archaic iron and steel tools which Col. Pearse, R. A., found in excavating some tumuli at Wurree Gaon, near Kamptee, in India, which tumuli are believed to date from about 1500 B. C., or the time of Moses; and whilst we have no such solid relics of the tools used by the Hebrew race, yet we know from words in the Hebrew language that they were well acquainted with iron in all its forms, and this discovery (which, if the date assigned by Col. Pearse be correct) shows at least that the contemporary nations were well acquainted with iron and steel; that their language, too, the Sanskrit, in its oldest forms, has corresponding words for iron, iron ores, &c.

Col. Pearse has presented his "find" to the trustees of the British Museum, and I lately was fortunate in receiving from Col. Pearse himself a full explanation of the several implements, which include gouges, spatulæ, ladles, and a variety of other articles.

RAILWAY NOTES.

BIG LOCOMOTIVES AND LONG TRAINS.—The Harrisburg *Patriot* says: For general use the heavy engines constructed within the past few years are not considered available. Although they are much more powerful than the ordinary locomotive and consequently can pull longer trains, they are not more service-

ble. A wreck occurred on the Philadelphia and Erie Railroad a few days ago from the fact that what should have been two trains was compressed into one, drawn by one of the large locomotives. Railroad men say that where long trains are hauled the momentum is so great that when an accident occurs to a front or centre car the wreck must prove a disastrous one, owing to the tremendous weight in the rear that nothing can successfully resist. For this reason they look upon the large engine as a failure—that is so far as the object intended is concerned, that of drawing sixty or seventy cars instead of an average train of thirty or thirty-five cars.

STRENGTH OF RAIL JOINTS.—At a late meeting in the hall of the Manchester (England) Institution of Civil Engineers, the following paper was read:

The introduction of the plain fish-plates now ordinarily used was a great advantage at the time to the railway world, mainly for preventing accidents by keeping the rails in position laterally, but since speed has increased, and weight of engines also, the plain fish-plates have been found deficient in one vital respect, viz., that of giving the rail joint the same stiffness and elasticity as the solid rail, so as to obtain one continuous road. As the stiffness of the joint with plain fish-plates principally depends upon the section of the rail and the fishing angle, often only a third of the stiffness of the joint is afforded as compared with that of the solid rail, but even in the best cases hardly more than half the rail stiffness is obtained. The introduction of steel rails necessitating the abolition of notches in the rail flange as destructive to the strength of the rail, has led to the design of the French or German fish-plate (*eclisse arret*) adapted for suspended joint, but requiring base plates at the joint sleepers. Even with this plan the experiments show only two-thirds of the strength of the solid rail is obtained, and as only one fish-plate of this description is generally used there is still less stiffness. Several other plans exist, more or less complicated, but as none have yet given the same stiffness as the rail, combined with cheapness in cost and maintenance, they have not come into general use, and the weak joint, with ordinary plain fish-plates, is still generally adopted. This has given rise to the design of the deep fish-plate for flange rails, similar to what has already been adopted for double-headed rail sections on many English railways. By using one fish-plate of this kind on the bolt-head side of the joint a material improvement is obtained, inasmuch as such joint possesses 80 per cent. of the stiffness of the solid rails. As regards the use of two deep fish-plates the experiments are conclusive as to the great increase in stiffness, being even stiffer than the rail both as regards strength and elasticity. Experiments on 2-feet supports show a load of 35-tons with more deflection on the rail than on the joint, proving a slight superiority of the joint, even in this respect best shown by the fact that the bolts were not the least hurt after such an extremely heavy test.

ENGINEERING STRUCTURES.

THE PROPOSED THAMES TUNNEL.—Mr. Barlow, C. E., has had an interview with the Works Committee of the Limehouse District Board of Works with reference to the question of the communication between the north and south of the Thames, by means of a tunnel under the river. Mr. Barlow, in explaining the nature of the proposal, said the tunnel would commence in the East India Road, and, by way of Robin Hood Lane, reach the river in the vicinity of Blackwall Stairs. The tunnel would terminate on the south side of the Thames, below Greenwich Hospital. As to the gradients, they would be only at the very moderate rate of 1 in 40. Having heard Mr. Barlow, the Committee of Works passed a resolution expressing their opinion that the proposed tunnel would be a great benefit to the public, and the Board agreed to memorialize the Metropolitan Board of Works in support of the scheme.

THE ALBERT BRIDGE, MONTREAL.—The *Montreal Daily Witness* gives particulars of the plans prepared by Mr. Legge, C. E., for the Royal Albert Bridge, which is to span the St. Lawrence at Montreal, a little lower down than the Victoria Bridge. It is to accommodate a railway track, carriage and cart traffic, and a tramway line, and provision is also to be made for pedestrians. Its total length will be 15,000 linear feet, or very nearly 3 miles. It will have one opening of between 500 and 600 feet clear span over the navigable channel of the St. Lawrence, with a height of 130 feet above the water at high tide; five of 300 feet each at the same height, four of 240 feet each, and 51 of 200 feet each. The estimated cost of the bridge is $4,000,000, and its erection, which will commence this spring, is expected to occupy three years. The Victoria Bridge, which has hitherto passed for being the largest in the world, is only 7,000 feet long, with one opening of 330 feet span, and 14 of 242 feet span. Its construction occupied six years, and the total cost was £1,260,000.

DREDGING AND HARBOR WORKS—THE INSTITUTION OF CIVIL ENGINEERS.—At the ordinary meeting of the session held on February 8th, Mr. Geo. Robt. Stephenson, president, in the chair, the paper read was on "Carlingford Lough and Greenore," by Mr. James Barton, C. E. It was stated that the mouth of Carlingford Lough was sheltered by a natural breakwater of rock, leaving a channel about 700 feet wide. Across this channel a bar of blue clay and boulders had existed previously to the works described, the depth of water being only 7½ ft. at low tide. Within the Lough the water was more than 18 ft. deep at low water over an area of 1,200 acres, affording safe anchorage. Although the cutting of a channel for navigation through this bar had been recommended by the Tidal Harbors Commissioners and by the Refuge Harbor Commissioners, it had not been carried out as a public work, but was undertaken locally under the Piers and Harbors Act, and was authorized by Parliament in 1864 to be executed by a Board of Commissioners, for which pur-

pose a sum of £80,000 was lent by the Public Works Loan Commissioners on the security of expected tolls. The exposed position of this work was somewhat unusual for dredging. The number of days in the year when the weather permitted the dredging to proceed varied from a minimum of sixty-seven in the year 1871, to a maximum of 131 in 1873, and upon many of these days the work was limited to two or three hours. The materials raised per season varied from 50,000 tons to 99,720 tons; the clay was generally blue and plastic, with boulders embedded, varying in size up to 4 tons in weight. The dredging plant had been specially designed, and was constructed by Messrs. Simons & Co., of Renfrew: it dredged in water 35 ft. deep, and lifted stones up to 30 cwt.; the larger ones were chained by divers and raised by a crane on the vessel's bow. The average lift for all days on which the dredger worked, whether one hour or sixteen hours, had been 850 tons; the maximum tonnage raised in one day was 4,000 tons. Some rock inside the Lough had been removed by first blasting on the surface with dynamite, and then dredging the broken-up rock. The channel already formed was 18 ft. at low water of spring tides for a width of 300 ft., and a further width of 50 ft. at each side had been cut to a depth of 14 ft. at low water. The channel was intended to be 600 ft. wide, and 18 ft. deep at low water The cost of the works, including insurance of plant and Parliamentary contests, &c., had been approximately 1s. 9d. per ton. The cost of the actual work for any one season varied from 1s. 4d to 1s. 6d. per ton. Two leading lighthouses had been erected to guide vessels through the channel, which was about three-quarters of a mile long. Within Carlingford Lough a point stretched out to the edge of deep water from the south side called Greenore, and here, three miles inside the bar, a marine station had been constructed and a railway to it formed from the Irish North-Western Railway at Dundalk, and another was in process of construction from Newry. This point afforded special facilities for a fixed hour steam service to Holyhead and elsewhere. The works at Greenore had been designed to provide for the convenient loading and unloading rapidly of steamers, with passengers, cattle, and goods, and to provide for the necessities of each kind of traffic.

The front of the land end of the wall below low water was formed of concrete blocks of about 3½ tons, set by divers, and the back face of the wall had been formed of concrete in sacks, containing about 1 cubic yard each, put down soft, and built in courses; and the hearting was of concrete deposited soft.

The foundation at the sea end had been formed of concrete blocks of 100 tons each, built upon the beach above low water in frames, and lifted, carried, and lowered between two barges by special machinery worked by hand. Two of these blocks, one upon the other, formed a length of 10 ft. of the wall up to low water. Above low water the wall had been built of heavy rubble limestone masonry, and it was fendered throughout. The cost of the works at Greenore had been £130,000. The cost of the quay wall, 45 ft. high on an average, had been, including extras, £27 8s. per lineal foot. The concrete used was one of Portland cement to six of sand, gravel, and stones. The cost of the concrete blocks of 100 tons each, when set, exclusive of barges and machinery, had been 30s. per cubic yard. That of the concrete built in the back face of the wall in sacks had been 23s. per cubic yard, while the cost of the liquid concrete set in the foundatians had been 18s. per cubic yard.

ORDNANCE AND NAVAL.

THE STEAMSHIP GREAT BRITAIN.—At a time when shipping legislation occupies the attention of many public meetings, and virtuous and indignant shipowners protest that their vessels are not rotten, but unfortunate, the following particulars of the Great Britain may be found suggestive. This famous vessel was the first iron steamer built by Brunel, and made her first voyage from Bristol to London in January, 1845, sailing from Liverpool to New York in August of that year. She is 322 ft. long, 51 ft. beam, and 32 ft. 6 in. deep, and has engines by Penn of 500-horse power. Since 1851 she has been, with the exception of her work during the Crimean war, a regular Australian trader, and has sailed over 1,000,000 nautical miles in that service, her last voyage to Melbourne being accomplished in 54 days. The vessel was surveyed recently, was found to be in a thoroughly sound condition, and to be one of the strongest vessels in the merchant service. And yet this vessel went on shore at Dundrum Bay—a spot which, we venture to think, would prove fatal to many of our modern iron-built ships.

THE MEDITERRANEAN NAVIES.—The military contributor of the *Cologne Gazette* observes, in an article on the navies of the Mediterranean, that by far the strongest naval power on that sea is Turkey. All the ironclads of her fleet are of recent construction, and most of them have come from the best English shipbuilders. The armor of the Turkish ironclads is from 5½ in. to 8 in. thick (two of the casemate ships have 9 in. plates), and they are armed with 8-in. and 9 in. Woolwich muzzle-loaders and Krupp breech-loaders. Turkey has four ironclad frigates of 3,050 horse power and 64 guns, six casemate ships each of 700 horse power and 5 guns, and three turret ships of 1,200 horse power and 11 guns, making in all fifteen ironclads with 9,250 horse power and 116 guns. To these should be added three ironclad gunboats of 240 horse power and 6 guns on the Danube, and two ironclad gunboats on the Lake of Scutari, each with 60 horse power and 2 guns. The screw ships are also for the most part well built and equipped. They consist of four ships of the line, thirteen frigates and corvettes, twenty-two avisos, and twenty-seven gunboats and coasting vessels, besides 101 transport ships, all large and mostly well armed. The actual strength of the available fleet of Russia on the Black Sea cannot at present be accurately estimated, but the writer thinks there can be

doubt that it is far inferior to that of the Turkish fleet. Austria has four ironclad casemate ships, of 3,600 horse power and 60 guns, and seven ironclad frigates, of 4,050 horse power and 980 guns. Three of these ships, however, are now being rebuilt, and most of the others do not fulfill the requirements of modern naval warfare, either as regards the thickness of their plates or the calibre of their guns. This remark applies even more to the Italian ironclad ships, several of which are to be sold by auction this month, in order to obtain funds for constructing new ones more suitable to modern requirements.—*Pall Mall Gazette.*

BOOK NOTICES.

NOTIONS PRATIQUE SUR L'ANALYSE CIMIQUE DES SUBSTANCES SACCHARIFERES, par M. A. TERRIEL. Paris: Dunod. For sale by D. Van Nostrand. Price $2.00.

This is a separate reprint of the second part of a former work bearing the title of *Portjeuille du Sucrier.*

The present volume contains all of the former that relates to analysis of the several products of sugar manufacture.

A thin octavo of 120 pages, illustrated, with 28 wood cuts.

ANNUAIRE, METEOROLOGIQUE ET AGRICOLE POUR 1876. Paris: Gauthier Villars. For sale by D. Van Nostrand. Price 80 cts.

This is a fair treatise on practical meteorology, containing complete descriptions of the best instruments in use.

The information regarding magnetic phenomena is of the fullest possible kind, and includes a magnetic chart of France. The automatic registry of barometric variations, and of force and direction of the wind, are exceedingly well represented by diagrams.

SIXTH ANNUAL REPORT OF THE ACUSHNET WATER BOARD. New Bedford: E. Anthony.

This report of the Water Supply for New Bedford, besides the details of local interest, contains the tabulated results of measurement of the duty of the two pumping engines, extending through the years 1874–5. The engines are a Worthington and a McAlpine. The summary is as follows:

	Hours.	Cost of coal.	Gallons pumped.
1874.			
McAlpine engine,.....	706	3,438	143,136,371
Worthington " ...	1,749	5,866	215,122,464
1875.			
McAlpine engine,....	509	2,685	113,278,900
Worthington "	2,431	8,180	303,665,904

TRAITE DES PARATONERRES, par A. CALLAND. Paris: Ducher & Co. For sale by D. Van Nostrand. Price $3.00.

A full-sized octavo volume, on the subject of Lightning-Rods, suggest an overdoing of the subject; yet when it is considered that to popularize the subject, the necessary preliminaries of electrical science must be presented, it must be acknowledged that an opportunity is offered to the writer to appear voluminous.

In the present treatise there is no attempt to encumber the work with useless matter; but the *theory*, *construction* and *utility* of lightning rods, is fully and fairly presented. Some suggestions for adaptation of forms of rod, and of their connections to the structures they are designed to protect, seem new and valuable.

One hundred and seventy pages of text and 70 wood cuts, are comprised in the volume.

THE INTERNATIONAL MERCANTILE TELEGRAPH CODE; compiled for the Use of Bankers, Merchants, Manufacturers, Contractors, Brokers, Shipowners, &c., and their Agents, for the economical and secret Transmission of Business Telegrams, the Ciphers being Words of ten Letters or under, to meet the Requirements of the Rules adopted at the St. Petersburg International Telegraph Conference of 1875. By the author of the "General Telegraph Code," the "Cotton Telegraph Code," &c. London: Hamilton, Adams & Co. 1876. For sale by D. Van Nostrand. Price $12.50.

No better recommendation of a book can be given than that it has passed into its thirty-third edition, which is announced of the "Cotton Telegraph Code." But as this code was mainly limited to one particular business, the author, a year or two back, submitted a second code for general use. This work, however, through some of its words having been made faulty by the rules of the International Conference, has led the author to prepare the above, which, as will be seen by the lengthy title, will meet nearly every want. Amongst other things, the compiler says of his work that it "contains nearly 20,000 sentences in cipher, applicable to all departments of commerce, and most judiciously selected; and not only is it the result of years of experience and study, but it also combines with this the numerous and invaluable suggestions received from mercantile men in all parts of the world. The sentences are, without exception, strictly of a business character, care having been taken to throw out any phrases that might be useless; and large as the number is, the author can confidently assert, that not one of them can be pointed out that is superfluous in a work of this sort. The ciphers are all plain English words, of not more than ten letters, chosen from a standard dictionary, and the greatest possible care has been taken to prevent too close a similarity; and no word, likely to be the name of a person, town, or ship has been used. Another feature of this book is, that a very large number of simple questions and answers are provided, which admit of endless combinations; and which are not to be found in any public or private code the author ever saw." This is saying not a little for the value of the book, but it is truly justified, as we have taken occasion to test. The saving effected by the code is from 75 to 85 per cent., while a mere novice can easily learn to use the work intelligently. Lastly, we may add, that words have been selected and room left for new phrases to suit purchasers, and it may be bought in sheets for interleaving or

extra copies of particular sections obtained, to prevent infringement of copyright, against which the author very significantly cautions the public.

DYEING AND CALICO PRINTING, INCLUDING AN ACCOUNT OF THE MOST RECENT IMPROVEMENTS IN THE MANUFACTURE AND USE OF ANILINE COLORS. By the late DR. F. CRACE-CALVERT, F.R.S., F.C.S. Edited by John Stenhouse, LL. D., F.R.S., &c., and Charles Edward Groves, F.C.S. London: Simpkin, Marshall & Co., 1876. For sale by D. Van Nostrand. Price $8.00.

The subjects treated of in the volume now before us possess a twofold interest—first as involving questions of pure science in the domain of organic chemistry; and secondly, as being of immense industrial importance to the country. It does not enter into our province to notice the work in its industrial aspect, but we have no hesitation in stating that author and editors have performed their task in a highly creditable manner. From every point of view the work will be found useful, and we can recommend it to the scientific chemist as well as to dyers and calico printers

The author, who died in 1873, had been occupied up to the time of his death in pre paring a treatise on coloring matters other than aniline. The present work has been edited from the author's MSS. with the addition of five chapters, forming a considerable portion of the book, on the coal-tar colors, by the editors.

The mode of treatment pursued is nearly the same for each dye. The natural history and source of the material from which the color is obtained are first given, then the chemical composition and mode of preparation or manufacture, and finally the method of application to the various fabrics described. The whole subject is profusely illustrated by specimens of dyed and printed fabrics pasted into the book.

The work is appropriately prefaced by an obituary notice of the author. The first chapter treats of color in general and the action of different forces, chemical agents, &c., on the various coloring matters.

Chapters II. and III. are entirely devoted to madder dyes, and contain, among much valuable chemical information, a description of Prof. Stoke's optical tests for alizarin and purpurin. The method of dyeing in Turkey red and the action of different mordants in madder and garancin printing is clearly explained, and the manufacture of artificial alizarin described. Chapter IV. treats of the red dyewoods—logwood, sapan, Lima, peach, and Brazil woods; also of safflower and alkanet. Chapters V. and VI. are devoted to indigo—this portion of the subject being described in considerable detail. Chapter VII. contains accounts of cochineal, kermes, gumlac, lac dye, lac lake, and murexide, while Chapter VIII. treats of orchil, cudbear, and litmus. In Chapter IX. some of the important yellow coloring matters are treated of, such as quercitron, fustic, Persian berries, weld, aloes, turmeric, annatto, &c.; while tannin matters form the subject of Chapter X., the most important of these being sumach and catechu. Chapter XI. contains descriptions of the methods employed for testing and determining the commercial value of particular samples of the various dye-stuffs. In this chapter will be found described some of the different forms of "colorometers" which have been devised for estimating the coloring power of dyes.

The portion of the work devoted to the coal-tar colors commencing with Chapter XII. begins with an account of the various bodies which have been found in coal-tar. A list of thirty-eight distinct compounds is given, and many more doubtless exist. The most important substance produced in the dry distillation of coal, so far as the dye manufacturer is concerned, is benzene. The conversion of this substance into aniline is explained, and the manufacture of magenta described, the chapter concluding with an account of safranine and some other aniline reds. Chapter XIII. treats of aniline violets, and blues such as mauve, the Hofmann and methyl-aniline violets, diphenylamine, and Nicholson's blues, &c. In Chapter XIV. we have a description of the greens, aldehyde, iodine, and methyl-aniline and the aniline yellows, phosphine, zinaline, &c. Chapter XV. treats of aniline black and brown, and the concluding chapter is devoted to the phenol, cresol, and naphthalene colors, including picric acid, corallin, aurin, and others. Not the least useful portion of the book will be found the tables at the end, which consists, first of a list of the madder-coloring matters, their formulæ, and reactions, and then a series of tables, which will enable the analyst to distinguish the different colors when fixed on fabrics.—*Nature.*

LEGAL CHEMISTRY. A GUIDE TO THE DETECTION OF POISONS, EXAMINATION OF STAINS, ETC., ETC., AS APPLIED TO CHEMICAL JURISPRUDENCE. Translated with additions from the French of A. NAQUET, Professor to the Faculty of Medicine of Paris. By J. P. BATTERSHALL, NAT. SC. D., with a preface by C. F. CHANDLER, PH. D., M.D., LL. D. New York: D. VAN NOSTRAND. Price $2.00.

The names of author and translator are a sufficient guaranty of the value of this handbook. Its convenient size will recommend it to students, who are generally overwhelmed by the bulkiness of the volumes in general use. The present work without covering so much ground as the larger treatises, is so compactly written as to be an exceedingly valuable substitute for them. We append the complete table of contents:

Introduction. Methods of Destruction of the Organic Substances—By means of Nitric Acid; by means of Sulphuric Acid; by means of Nitrate of Potassa; by means of Potassa and Nitrate of Lime; by means of Potassa and Nitric Acid; by means of Chlorate of Potassa; Chlorine; by means of Aqua Regia; Dialysis. Detection of poisons, the presence of which is suspected—Detection of Arsenic; Method used prior to Marsh's test; Marsh's

test; Raspail's test; Reinsch's test. Detection of Antimony — Flandin and Danger's Apparatus; Naquet's apparatus. Detection of Mercury—Smithson's pile; Flandin and Danger's apparatus—Detection of Phosphorus—Orfila's method; Mistcherlich's method; Dusart's method, as modified by Blondlot; Fresenius and Newbauer's method; Detection of Phosphorus by means of bisulphide of carbon; Detection of Phosphorus Acid; Estimation of Phosphorus. Detection of Acids — Hydrochloric Acid; Nitric Acid; Sulphuric Acid; Phosphoric Acid; Oxalic Acid; Acetic Acid; Hydrocyanic Acid. Detection of alkalies and alkaline earths. Detection of chlorine, bromine and iodne—Chlorine and Bleaching Chlorides; Bromine; Iodine. Detection of Metals; Detection of alkaloids and some ill-defined organic substances; Stas's method; Stas's method as modified by Otto; Stas's method as modified by Uslar and Erdman; Rodgers and Girdwood's method; Prollius's method; Graham and Hofman's method; Application of Dialysis in the detection of Alkaloids; Identification of the Alkaloid; Identification of Digitaline, Pierotoxine and Colchicine. Method to be employed when no clew to the nature of the Poison present can be obtained—Indicative tests; Determinative tests. Miscellaneous Examinations—Determination of the nature and color of the hair and beard; Determination of the color of the hair and beard; Determination of the nature of the hair; Examination of Fire-arms; The gun is provided with a flint-lock and was charged with ordinary powder; The gun is not provided with a flint-lock; Detection of human remains in the ashes of a fire-place; Examination of writings; Examination of writings, in cases where a sympathetic ink has been used; Falsification of coins and alloys; Examination of alimentary and pharmaceutical substances; Flour and Bread; Fixed Oils; *a* Olive Oil intended for table use; *b* Olive Oil intended for manufacturing purposes; *c* Colza Oil; *d* Hemp-seed Oil; *e* Linseed Oil; Milk; Wine; Vinegar; Sulphate of Quinine; Examination of blood stains; Examination of spermatic stains.

The following abstract from the author's introduction, indicates some points of excellence characteristic of the book:

"The detection of poisons, although perhaps the most important, is not the only subject that may come within the province of the legal chemist; indeed, it would be somewhat difficult to define, *a priori*, the multitude of questions that might arise. In addition to cases of supposed poison, the following researches are most often required:

1. The examination of fire-arms.
2. The analysis of ashes, in cases where the destruction of a human body is suspected.
3. The detection of alteration of writings, and of falsification of coins and precious alloys.
4. The analysis of alimentary substances.
5. The examination of stains produced by blood and by the spermatic fluid.

Each of these researches justly demands a more extended consideration than the limits of this work would permit. The several subjects will be treated as briefly as possible, and at the same time, so as to convey an exact idea of the methods employed, leaving to the expert the selection of the particular one adapted to the case under investigation. We will first mention the methods used in the search for toxical substances. The poisons employed for criminal purposes are sometimes met with in a free state, either in the stomach or intestines of the deceased person, or in the bottles discovered in the room of the criminal or the victim. Under these circumstances, it is only necessary to establish their identity by means of their chemical properties, as directed in the general treatises on chemistry, or by their botanical, or zoological character, in case a vegetable or animal poison, such as cantharides, has been administered. Examinations of this class are extremely simple, the analysis of the substances found, confined to a few characteristic reactions, being a matter of no great difficulty. We will not here dwell longer upon this subject, inasmuch as the analytical methods used are identical with those employed in more complicated cases, with the sole difference that, instead of performing minute and laborious operations in order to extract the poisons from the organs in which they are contained, with a view of their subsequent identification, we proceed at once to establish their identity. The directions given in regard to complicated investigations apply, therefore, equally well to cases of a more simple nature. The detection of poison mixed with the organic substances encountered in the stomach, or absorbed by, and intimately united with the tissues of the various organs is more difficult. If, however, other information, than chemical can be obtained, indicating the poison supposed to be present, and the presence or absence of this one poison is the only thing to be determined, positive methods exist which admit of a speedy solution of the question. When, on the other hand, the chemical expert has not the advantage of extraneous information, but is simply asked,—whether the case be one of poisoning?—nothing being specified as to the nature of the poison used, the difficulty of his task is greatly increased. Up to the present time, the works on Toxicology have, it is true, given excellent special tests for the detection of particular poisons; but none have contained a reliable general method, which the chemical expert could use with the certainty of omitting nothing. Impressed with this need, we proposed, in 1859, in an inaugural dissertation then presented to the Faculty of Medicine, a general method, which, after some slight modifications, is now reproduced. The special methods which allow of the detection of various individual poisons will, however, first be indicated. In cases where the poison is mixed with organic matter, the latter must be removed as the first step in the investigation, as otherwise the reactions characteristic of the poison searched for would be obscured. When the poison itself is an organic substance, this separation is effected by processes modified according to the circumstances. If

the detection or isolation of a metallic poison is to be accomplished, the most simple method consists in the destruction of the organic substances. The various methods for effecting this decomposition will now be described.

MISCELLANEOUS.

TRAMWAY LOCOMOTIVE.—A new tramway locomotive is being experimented with on a private tramway, at the quarries of Avron-Neuilly, near Neuilly-sur-Marne. The motive power is compressed air, mixed with steam. For a journey of three-eighths of a mile, with twenty-five passengers, a charge of 800 litres of compressed and heated air is found to be sufficient, the vehicle weighing 4,500 kilogs. The journey is made without noise or smoke, no steam is given off, and stoppage is easily effected.

PURIFICATION OF SMOKE.—An apparatus for washing smoke, and so depriving it of its character of a nuisance, is in operation at a factory at Ménilmontant, Paris. A fine shower of water, traveling in the direction of the smoke, and at five times its velocity, is projected into the chimney, where it mixes with the smoke, taking up the soluble gases and precipitating the impurities carried up with the smoke by the draught. The foul water is discharged into a cistern, where it is collected, and a fine black paint is got from it.

MINING INDUSTRY IN AUSTRIA.—From the official Austrian report on mining we learn that in 1874, there were 1,801 mining undertakings in activity in the Austro-Hungarian Empire, classified into 370 coal mines, with 36,980 workmen; 863 brown coal mines, with 27,449 workmen; 243 iron mines, with 8,753 workmen; and 325 mineral works of miscellaneous character, employing 14,249 workmen. Austria had 227 smelting works, with 10,730 workmen, comprising 125 blast furnaces, with 9,055 workmen.

A NEW composition, being a bad conductor of heat, is recommended by M. S. Coline, a French engineer, for the bearings of all kinds of machines, wheels and axles, as not requiring any lubrication. The following is the recipe for the composition:—Take about 25 per cent. of abestos, and the same of plumbago, and mix them very intimately and carefully together; then add sufficient liquid silicate of soda or potash to reduce the whole to a half dry paste. The paste must then be submitted to the action of a hydraulic or other press, till it is converted into a solid mass which is afterwards dried either in a furnace or by exposure to the air, until all moisture has disappeared. The bearings may either be turned out of the block or moulded from the composition while in the moist state. When the bearing is finished it is steeped in hot melted paraffine, mineral wax, or in a solution of paraffine, benzole, or other mineral oil, until all the pores in the composition are filled up.

THERE is at length a fair prospect that telegraphic communication with the Channel Islands and the Isle of Man will be re-established within a very short time. The cable ship Caroline has shipped at Silvertown some twenty-five miles of new cable for the Channel Islands, to replace a great portion of the faulty cable now submerged between Dartmouth and Guernsey. Having completed this portion of her endertaking, she will proceed to the Isle of Man to recover a portion of the faulty cable submerged there, and to lay new shore ends in readiness for a new deep sea section of cable at present in course of manufacture. A month or six weeks of fine weather will probably suffice for the completion of the whole of these important operations; and towards the middle or end of September we may hope to be once more in direct communication with the Channel Islands and the Isle of Man.

OF THE ANNUAL REPORT OF STATISTICS OF LOWEL MANUFACTURES, the following is an abstract:

Merrimack Manufacturing Co. — Capital stock, $2,500,000; number of mills, 5 and print works; spindles, 159,464; looms, 3,941; water wheels, 6 turbines 5 ft., 4 do. 8 ft. 6 in. diameter; steam power, 40 engines, 3,800 horse power.

Hamilton Manufacturing Co.—Capital stock, $1,200,000; number of mills, 5 and print works; spindles, 56,080; looms, 1,546; water wheels, 9 turbines; steam power, 17 engines, 943 horse power.

Appleton Co.— Capital stock, $600,000; number of mills, 3; spindles, 42,488; looms, 1,202; water wheels, 5 turbines; steam power, 2 engines, 400 horse power.

Lowell Manufacturing Co.—Capital stock, $2,000,000; number of mills, 1 spinning, 2 carpet, 1 fine worsted; spindles, 19,700 worsted and wool, 2,816 cotton; looms, 297 power carpet, 75 lasting; water wheels, 2 turbines, 10 feet diameter, 1 do. 8 feet 4 inches diameter; steam power, 3 engines, 825 horse power.

Middlesex Co. — Capital stock, $750,000; number of mills, 4 and dyehouses; spindles, 13,340; looms, 230 broad; water wheels, 1 turbine, 5 breast, 12 and 17 ft.; steam power, 1 engine, 125 horse power.

Tremont & Suffolk Mills.—Capital stock, $1,200,000; number of mills, 4; spindles, 93,528; looms, 2,300; water wheels, 8 turbines, 8 feet 4 inches diameter; steam power, 2 engines, 1,000 horse power.

Lawrence Manufacturing Co.—Capital stock, $1,500,000; number of mills, 5 and dyehouses; spindles, 92,000; looms, 2,260; water wheels, 11 turbines, 9 ft.; 1 do. 80 in.; 1 do. 24 in.; 2 do. 48.; 1 do. 42 in.

Boott Cotton Mills.—Capital stock, $1,200,000; number of mills, 6; spindles, 112,752; looms, 2,552; water wheels, 6 turbines, 7 feet 8 inches, 1 do. 6 ft. 8 inches, and 2 do. 6 feet; steam power, 1 engine, 440 horse power.

Massachusetts Cotton Mills.—Capital stock, $1,800,000; number of mills, 6; spindles, 101,720; looms, 2,808; water wheels—diam., 3 turbines, 10 ft.; 2 do., 9 ft.; 1 do., 6 ft.; 4 do., 5 ft.; steam power, 1 engine, 200 horse power.

Lowell Bleachery.—Capital stock, $300,000; number of mills, bleachery and dyeworks; water wheels, 1 turbine; steam power, 2 engines, 1,050 horse power.